JUNE 1965 ER-4073

UNIVERSAL PILOT SUPPORT COUCH TEST DATA BOOK

CONTRACT N62269-2759

FOR THE AVIATION MEDICAL ACCELERATION LABORATORY
NAVAL AIR DEVELOPMENT CENTER
Johnsville, Pennsylvania

PREPARED BY W. S. THAYER
L. M. McCLERNAN

BY AIRCRAFT ARMAMENTS, INC.
COCKEYSVILLE, MARYLAND

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UNIVERSAL PILOT COUCH

DATA BOOK

I. INTRODUCTION

In a recent development program under Contract N62269-2759 for the Aviation Medical Acceleration Laboratory (AMAL), Naval Air Development Center, Johnsville, Pennsylvania, AAI conducted a thorough study of a full-body, soft cushion couch as an effective means of protecting pilots and crew members from severe dynamic environments. A prototype couch was designed, fabricated and tested by AAI.

Phase I of this program involved the study of various foams, design of a couch configuration, prediction of testing results, testing in shock, acceleration and vibration environments and a comparison of predicted results with actual results.

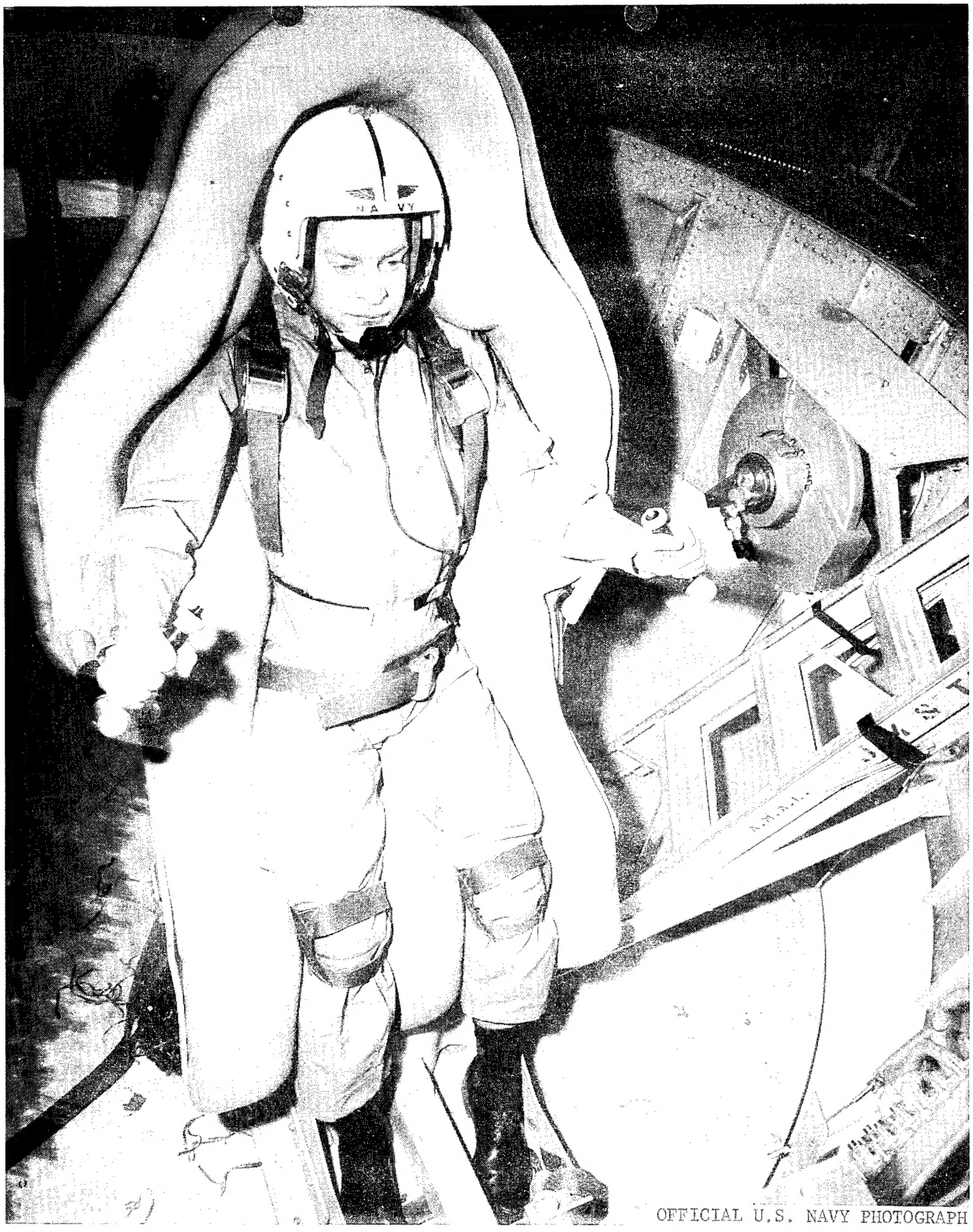
Phase II of this program involved development of an articulated seat and leg support couch and, testing of the couch, only if the predictive method of phase I were not satisfactory. As an alternative to phase II testing, a data book has been prepared to show the validity of the predictive methods.

The soft cushion concept was originally developed and patented by Hitchcock, L. and Morway, D. A. at AMAL. This concept involves the utilization of a composite cushion constructed of several layers of foam materials with different deflection characteristics. When used in proper combination, a smooth non linear load versus deflection response is obtained. It was predicated that a given environment could be tolerated by a calculable combination of foams. Design limits were initially established based on human tolerance. A number of foam materials were investigated and their theoretical response to the various environments was calculated. From these calculations, a series of foams were selected and combinations of these were tested to determine their response to compressive loading.

Another important factor in the design of the couch was the body position of the subject during exposure. The couch configuration and a restraint system were designed to maintain the body in a position considered optimal for the known force vector.

With these tasks completed the couch was tested at Dayton T. Brown on Long Island and in the Johnsville Human Centrifuge. See Figure 1 for completed couch assembly mounted in Johnsville Centrifuge.

The following sections of this data book present the data pertinent to justify a predictive method of foam cushioning design for unique applications.



UNIVERSAL COUCH DURING TESTS IN THE JOHNSVILLE CENTRIFUGE

FIGURE 1

II. FOAM SELECTION

A variety of foams were evaluated for load-versus deflection, hysteresis, creep, resiliency, energy absorption, elongation, and dynamic cushioning. Materials were sought which satisfied the following requirements:

a) light weight
b) repeatable load deflection characteristics
c) high energy absorption, low resiliency
d) non-toxic
e) flameproof
f) tear resistant
g) moderate damping (μ = .2)
h) dimensionally stable, low creep rate
i) non-aging
j) low compression set
k) temperature stability
l) compression versus deflection range within the cushion load requirements.

Preliminary calculations indicated that a body pressure loading of about 0.2 psi per G would be expected for subjects supported in a full-body couch except at the buttocks where the pressures beneath the ischial tuberosity may vary up to 1.0 psi. The maximum foam pressure would be 12 psi which may be encountered at 60 G shock input.

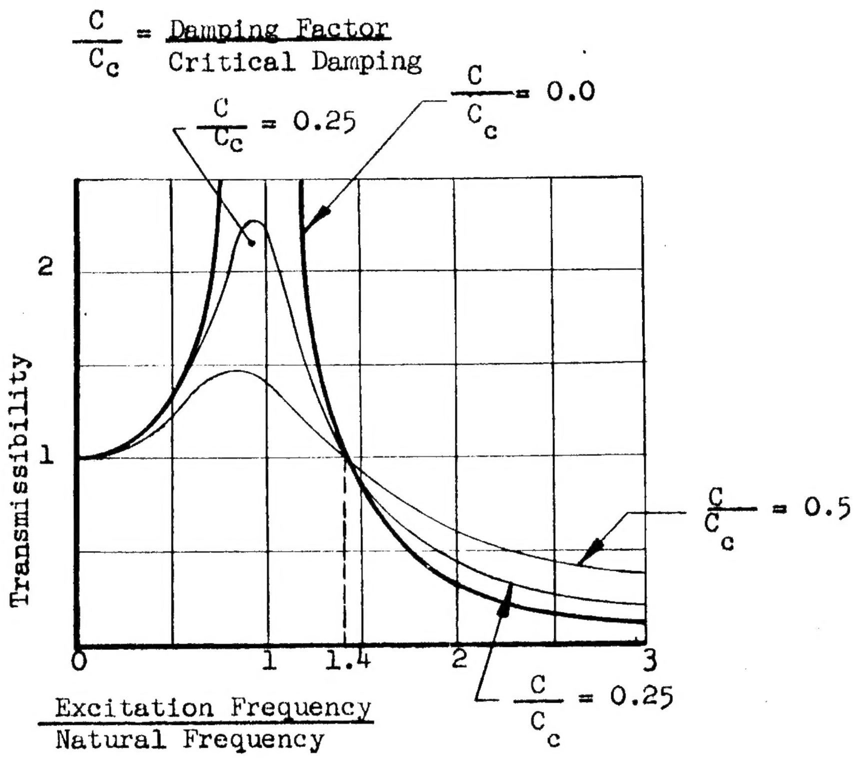
The cushion design requirements for the vibration environments are illustrated by a plot of transmissibility versus frequency ratio as shown in Figure 2. These curves show that system damping is desirable for reducing transmissibility in the excitation frequency range below 1.4 times the natural frequency while in the excitation frequency range above 1.4 times the natural frequency, damping increases transmissibility. A reasonable compromise is a moderate damping ratio of approximately .25. This curve further shows that for a man/seat system exposed to a wide range of random excitation frequency inputs, a low system natural frequency will afford minimum transimssibility over the greatest possible range. We have assumed here that the pilot and seat cushion can be represented by a single degree of freedom system with viscous damping.

For acceleration and shock, an optimum pressure versus delfection curve for a multi-layered couch cushion is shown in Figure 3.

A G scale based on a nominal body pressure loading of 0.2 psi per G is given as an additional ordinate scale.

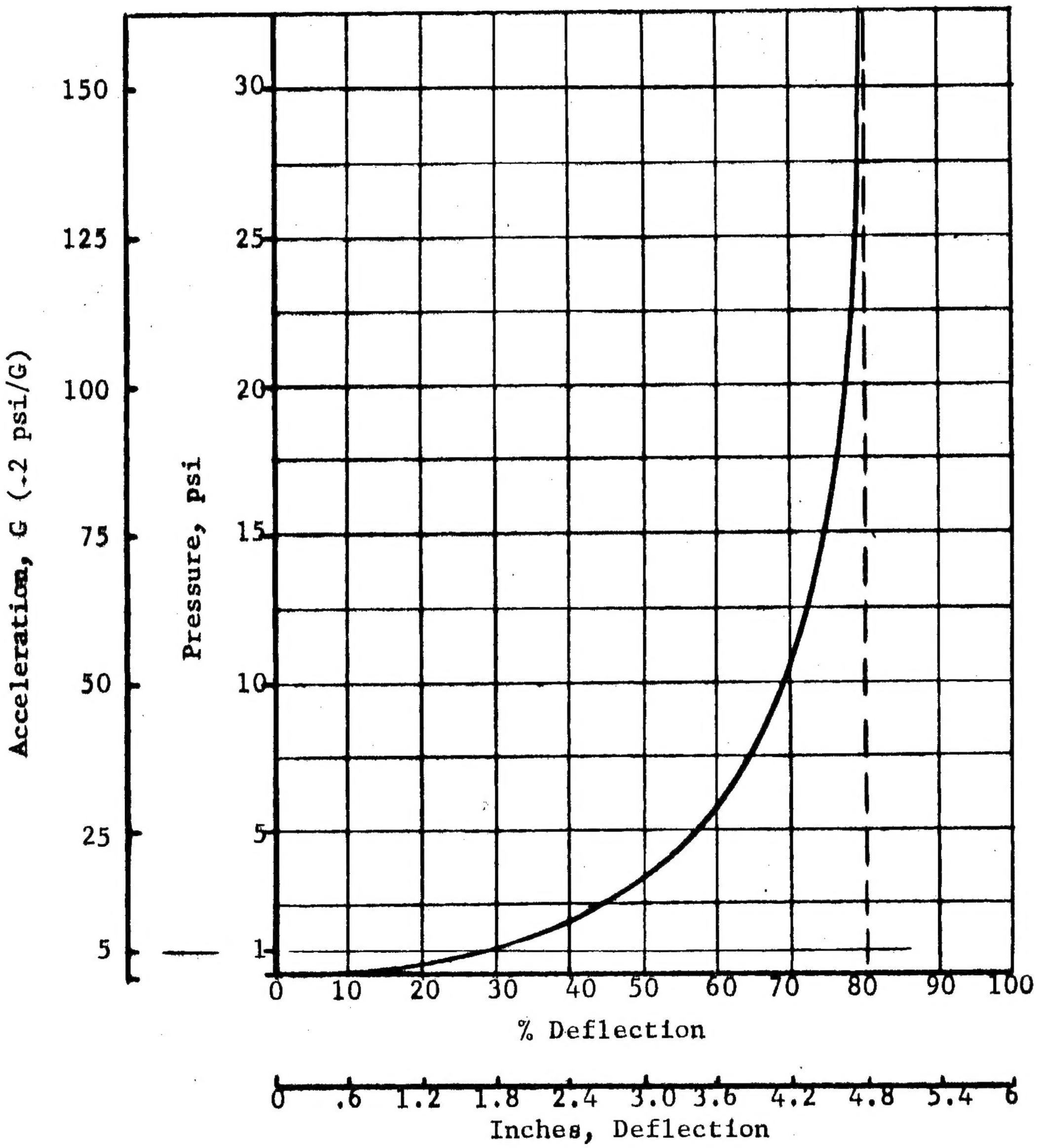
Since no single foam covers this wide load-deflection range, a composite combining the limited deflection ranges of several materials was necessary.

It was found that a 2-inch layer of soft urethane, a 2 inch layer of firm urethane, and a 2 inch layer of polyethylene would most nearly match the optimum cushion curve. A soft seam latex adhesive was used to body the various layers together.



Transmissibility versus Frequency
Damped Single Degree of Freedom System

Figure 2



OPTIMUM CUSHION DEFLECTION CURVE

Figure 3

The soft outer layer is designed to reduce the natural frequency to 4-6 cps and provide universality by contouring to a range of body sizes. The medium middle layer, while firm to the touch, is sufficiently soft to deflect further to avoid pressure points at the body protuberances. The medium layer will absorb low-level shock energy and reduce the energy of high level shock inputs. The firm inner layer is designed primarily to reduce the severity of impact. It prevents abrupt bottoming and reduces the rebound from high energy shock. The inner layer maintains the couch configuration and is not affected by the vibration and acceleration levels of human tolerance.

The outer layer is covered by a highly elastic coating which is sprayed in place. Hypalon, by Du Pont, was used because it provided surface wear resistance and a significant reduction in surface friction.

For fabrication of this prototype couch, a hand layup of epoxy and fiberglass cloth was used. The total shell thickness was .3 inches. Since we tested the couch in a number of different environments, a general purpose support frame was fabricated and attached to the fiberglass shell. This frame included two sets of attachment rails so that it could be readily mounted on any flat surface in either the normally seated or normally supine positions.

In all fourteen different foams were investigated:

1. Urethane Polyester
2. Urethane Polyether
3. Latex
4. Open celled Polyvinyl Chloride
5. Closed Celled Polyvinyl Chloride
6. Polyethylene
7. Polystyrene
8. Neoprene
9. Natural Rubber Foam
10. Butyl Sponge
11. Butadienestyrene
12. Closed celled Silicone rubber
13. Open celled Silicone Rubber
14. Rubberized hair

They were evaluated against eight characteristics. References for the various foams were drawn from the following:

1. Modern Plastics Encyclopedia for 1964, Vol. 41 No. 1A pp 47, 348, 359, 361. Modern Plastics, 770 Lexington Avenue, New York 21, N. Y.

2. Plastics Engineering Handbook, Society of the Plastics Industry, Reinhold Publishing Co., New York, N. Y., Third Edition, 1960

3. Concise Guide to Plastics, Herbert R. Simonds, Reinhold Publishing Co., New York, N. Y. 1957 pp. 106.

4. Burton, Walter E., Engineering with Rubber, Maple Press Co., York, Penna. 1949, pp 394.

5. Stanley Lippert, Cellular Plastics in Air Transportation, Douglas Aircraft Co., Santa Monica, California.

6. Design Criteria for Plastic Package Cushioning Materials, Plastic Report No. 4, Plastics Evaluation Center, Picatinny Arsenal, Dover, N. J.

7. Materials in Design Engineering, Oct. 1963, Vol. 58 No. 5, Reinhold Publishing Co., 430 Park Avenue, N. Y. 22, N. Y., pp. 238.

8. Sales Brochure, Toyad Corp., Latrobe, Penna.

9. Communication, from W. J. Walsh, Burlington Mills, Burlington, Wisconsin. 13 Aug. 1964.

10. Sales Brochure, Johns Manville, Chicago 19, Ill.

11. Sales Brochure, Ethafoam, Dow Chemical Co., Plastics Dept., Midland, Mich.

12. Foams for Cushioning, Product Engineering, 9 Dec. 1963.

13. (Resiliency Tests) Ball Drop Method, AAI Mechanical Lab., Oct. 1964.

The results of the evaluation against the eight characteristics categories are shown on Table I.

TABLE I

Material	Density	Creep	Compression Set	Resiliency	Temp. Effects	Compressive Strength, psi	Elongation %	Dynamic Cushioning
Urethane Polyether & Polyester (1) General Good Comfort cushioning, light weight, resistant to chemicals, non-aging, non-allergic, non-toxic, will not ab- sorb moisture or odors, low cost, excellent tear resistance, dimensionally stable. (6) Excellent for foam-in-place	(1) 1-4 lb/ft^3	(6) Polyether 10% at .25 psi for 5 hours	(1) 10% (6) 70 hrs. at 158^{o} Polyester 15.6% Polyether 17.2%	(1) Ball Drop Polyester 25-45% Polyether 45-55% (1) Compression Resilience Polyester 38-65% Polyether 55-65% (6) Hysteresis Polyester 58.6% Polyether 50.9% (8) Yerzley Resiliency 21.4% Chemfoam Dr (13) UU15 32-37% UU44 41-44%	(1) 260^{o}F max (1) Poor heat trans- fer characteris- tics K = .16 BTU/HR/ft^2/^{o}F (5) Stiffens at -60^{o}F (5) Slight softening at 160^{o}F (6) 80% impact g increase at 0^{o}F (6) 25% strain 7.4 psi at -40^{o}F 2.1 at 0^{o}F 1.0 at 160^{o}F (1) Self-extinguishing when specially com- pounded	(1) 0.2 to 2.0 psi at 25% defl. (1) Polyester 25% .50-.85 50% .55-1.30 75% 1.50-3.75 (1) Polyether 25% .18- .55 50% .27- .70 75% .72-2.00 (1) .5 x 10^{-3} loss tangent	(1) 125-500	(6) h = 30 in. Polyester 2.0 in 42-60G 3.0 in 37-40G 4.0 in 28-30G h = 36 in. 1" 126G 2" 60-70G 3" 34-50G 4" 24-34G 5" 19-24G
Latex (3) Poor tensile strength, poor chemical resistance, 250,000 cells/in^3 (4) Good shock and vibration absorber, mildew and vermin resistant, easily washed, long life, pro- duced cored and uncored, dimensionally stable.	(1) 5.5 lb/ft^3 (3) 2-25 lb/ft^3 (4) 3.1 extra lb/ft^3 soft 4.2 soft lb/ft^3 5.2 med " 6.3 firm "		(5) Good	(13) Soft 30% Firm 57-59% Fabric Covered -50%	(5) Slightly at -60^{o}F and at 160^{o}F (6) 80% impact G increase at -20^{o}F (3) Flammable	(4) 25% deflection Extra soft .1 -.2 Soft .2-.5 Med. .5-.8 Firm .8-1.7		

TABLE I (Continued)

Material	Density	Creep	Compression Set	Resiliency	Temp Effects	Compressive Strength, psi	Elongation %	Dynamic Cushioning
Polystyrene (Styrafoam)	(1) 1-5 lb/ft^3	(6) 60% at 25% strain for 5 hr.	(6) 70 hr. at 158^oF 100%	(6) Hysteresis 63.5% at 20% compression (1) .14-.20 ft lb/in impact str.	(1) 175^oF max. (1) Self extinguishing	(1) 14-115 psi		(1) b = 30 in. 2.0 in. 70-73G 3.0 in. 49-50G 4.0 in. 34-38G 6.0 in. 23-26G
Neoprene	(1) 10-30 lb/ft^3	(6) 20% at 25% strain for 5 hr.	(6) 70 hr. at 158^oF 10%	(6) Hysteresis 19% at 20% compression (13) 42-49%	(1) 180^oF max (7) Non-flammable	(7) 25% .15-.80 psi 50% .35-2.4	(7) 300-400%	
Natural Rubber Foam	(7) 6-7 lb/ft^3		(10) 22 hr. at 158^o F 15%	(12) 50-90% (13) 41-56%	(7) 130^oF max (7) Flammable	(7) 25% .15-.80 psi 50% .35-2.40 psi	(7) 300-380%	
Butyl Sponge	(1) 4.5 lb/ft^3				(1) 160^oF max			
Butadiene-styrene	(6) (5) (7) 1-2 lb/ft^3	(6) 20% at 25% strain for 5 hrs.	(6) 70 hr. at 158^oF 26.5%	(6) Hysteresis 34.8% at 20% compression	(7) 140^oF max service temp. (7) Flammable	(7) 25% .15-.80 psi 50% .35-2.4 psi	(7) 180-350%	
Silicone Rubber Closed or Open Cell	(1) 13-15 lb/ft^3		(1) 0% at 22 hr. at 25^oC	(1) High (13) 72%	(7) 500^oF max -130^oF min	(2) 25% Defl. 2.0 psi 50% 5.0 psi	(1) 50% (7) 40%	
Rubberized Hair	(6) 1.8 lb/ft^3	(6) 45% at 25% strain for 5 hrs.	(6) 70 hr. at 158^o F 68.7%	(6) Hysteresis 43.7% at 20% compression (13) 50%	(6) 50% impact G increase at -20^oF			

TABLE I (continued)

Material	Density	Creep	Compression Set	Resiliency	Temp Effects	Compressive Strength, psi	Elongation %	Dynamic Cushioning
Polyvinyl Chloride Open Cell	(1) 3 and up lb/ft^3		(1) 15% 22 Hr at 158°F		(6) 60% impact G increase at 0°F	(1) .06 to 10 psi at 25% Defl.	(1) 75-300	
Closed Cell (3) Good tensile strength, good chemical resistance	(1) 4-25 lb/ft^3		(5) Poor (9) 0%	(13) #10 Ensolite 54% Ensolite M 46% Ensolite AL 16%	(12) 200°F max (5) Stiffens at -60°F depending upon the plasticizer (5) Slight softening at 160°F (1) Self extinguishing	(1) 5-8 psi at 25% Defl.	(9) 120%	
Polyethylene (Dow Etha-foam) (1) Tough, moisture resistant, chemically resistant, flexible, high impact absorption	(1) 2 lb/ft^3	(6) 25% at 20% strain for 5 hr.	(6) 98.5% 70 hr. at 158°F	(1) Rebound 30-35% (13) 30% (1) energy retention 25% Defl. 56% 50% Defl. 55% 75% Defl. 33% (6) Hysteresis 36.7% at 30% compression (6) Energy absorption 2 in/lb/in^3 at 10 psi = 30% strain	(1) 160° F max K = .35 btu/hr/ft^2/°F (6) Thermoplastic max range -60 to + 160°F (11) Melts on exposure to heat. Burns on exposure to open flame	(11) 10 psi at 25% 15 psi at 50%	(7) 300%	(6) b = 30 in. 2.0 in. 57G

Static deflection tests were performed at AAI using 8" x 8" x (variable)" samples and 4" x 4" x (variable)" samples. Tests were performed using single layers of foam and multiple layers of variable density foam. A 4" x 4" foot was used in all tests. The results of the deflection tests are shown in Figures 5 through 42. Figures 5 through 20 are based on data collected with a 4" x 4" foot pressed into the center of an 8" x 8" sample of varying thickness. Figures 21 through 28 are based on data collected with 4" x 4" foot pressed onto a 4" x 4" sample of varying thickness. Figures 29 - 40 are deflection data based on manufacturers' published data. Figures 41 and 42 are data collected by AMAL on the foam used in the original AMAL couch minus any covering material.

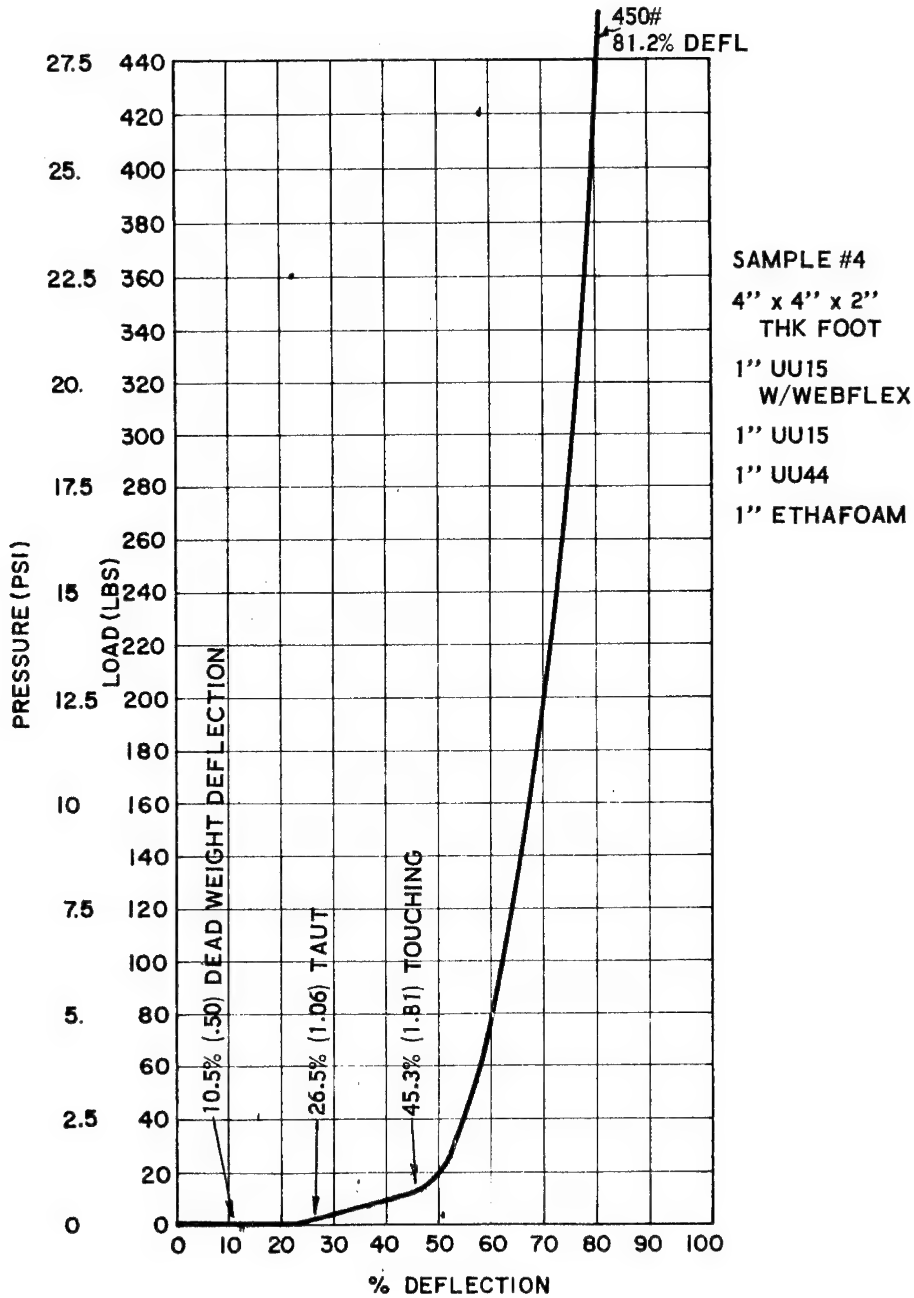
It must be remembered that testing a sample of relatively small size on a flat surface will show results which are predictably different from those gathered with large contoured foam sections in dynamic test. In general, due to the effects of edge factors, results of the latter will be steeper and shifted to the left as though the foam were firmer..

The foam selected for couch comfort liner was a six-inch composite, two inches of soft urethane, two inches of firm urethane and two inches of polyethylene (Dow Ethafoam). Static load versus deflection for this cushion is shown in Figure 28 from results in AAI-conducted tests and in Figure 40 from manufacturers" supplied data.

The basis for the selection of this particular foam combination was a comparison of the load vs. deflection curves and characteristics data given in Table I.

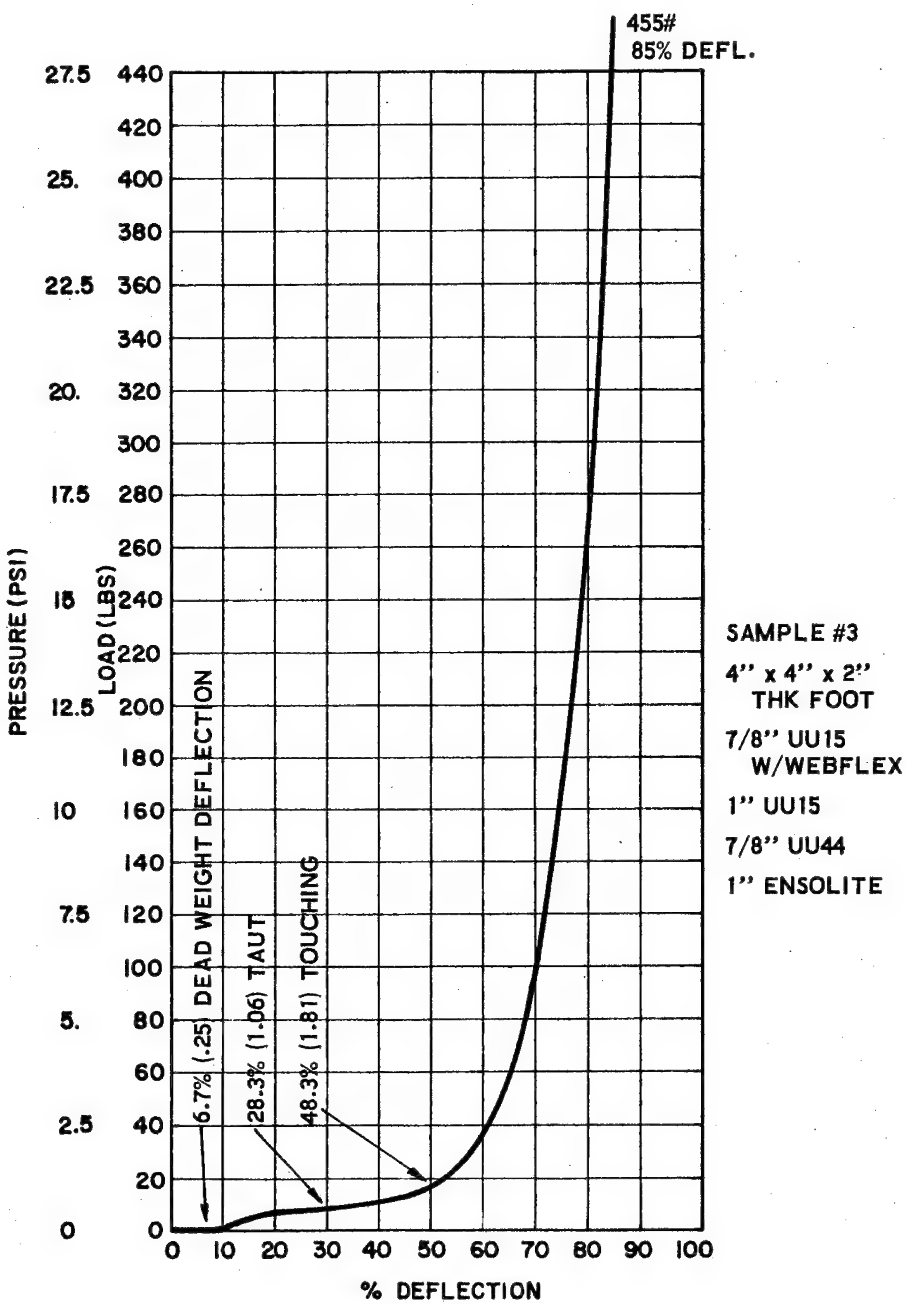
On the basis of the test data in the other sections of this report, the foam composite whose response is shown in Figure 20 was chosen for the second couch configuration (or Model B version of the couch which is articulated). It may be of interest to the reader to compare Figures 20 and 28 at this point and predict in his own mind the expected differences in couch responses.

Graphs of test samples covered with the Webflex synthetic rubber coating used in the Model A couch are so noted. Notations of "taut" indicate the point where the compression test apparatus was initially stressed. Notations of "touching" indicate the point where the foam completely wrapped around the foot of the compression fixture.



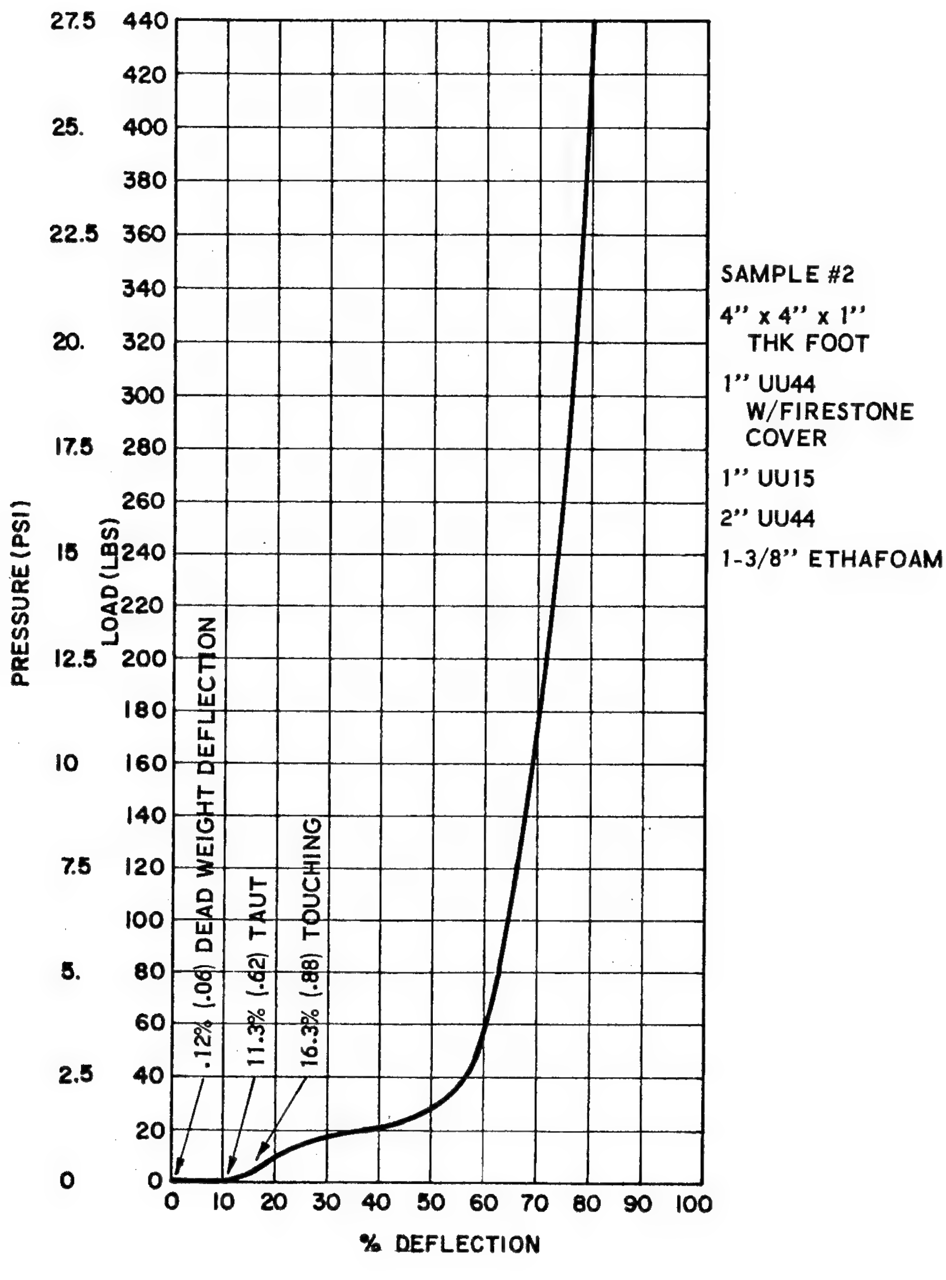
Foam Static Deflection Curve

Figure 5



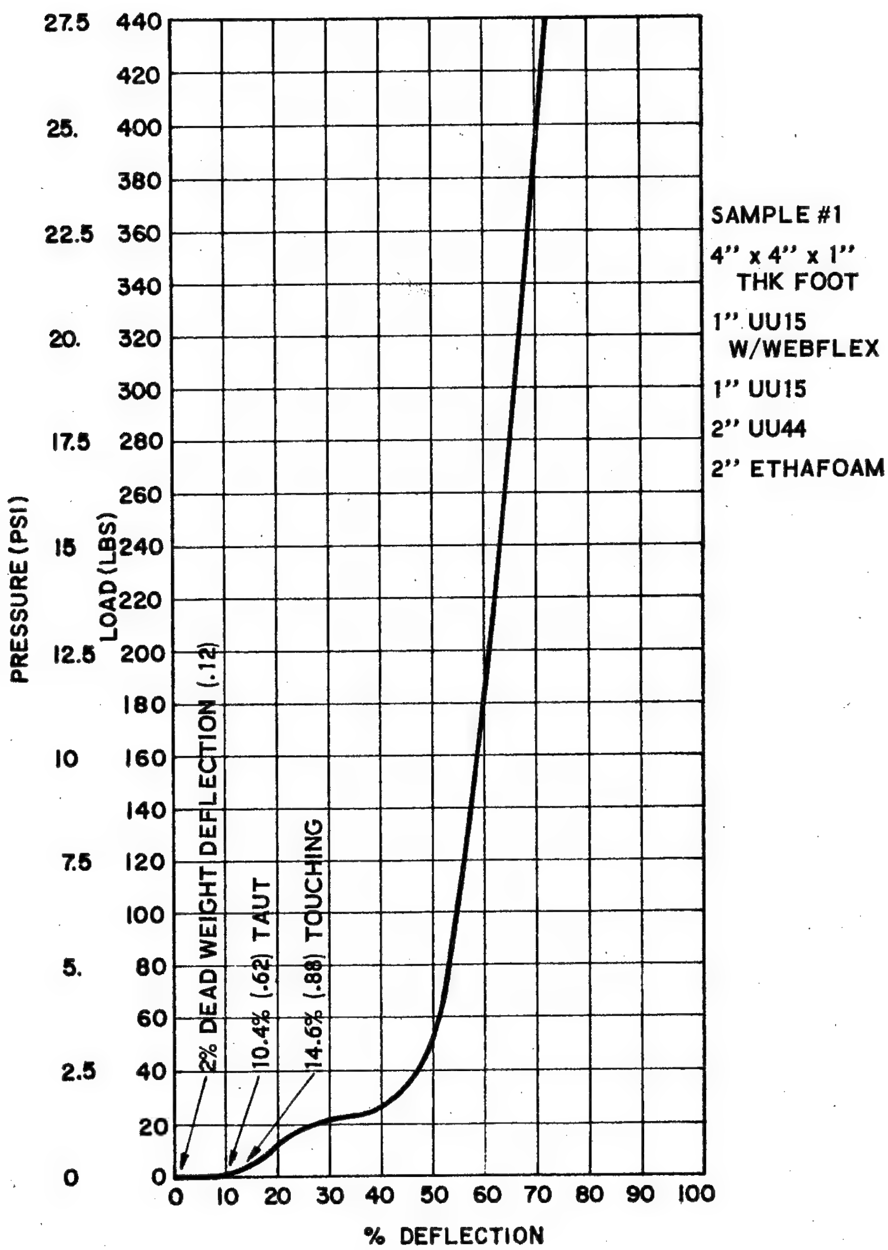
Foam Static Deflection Curve

Figure 6



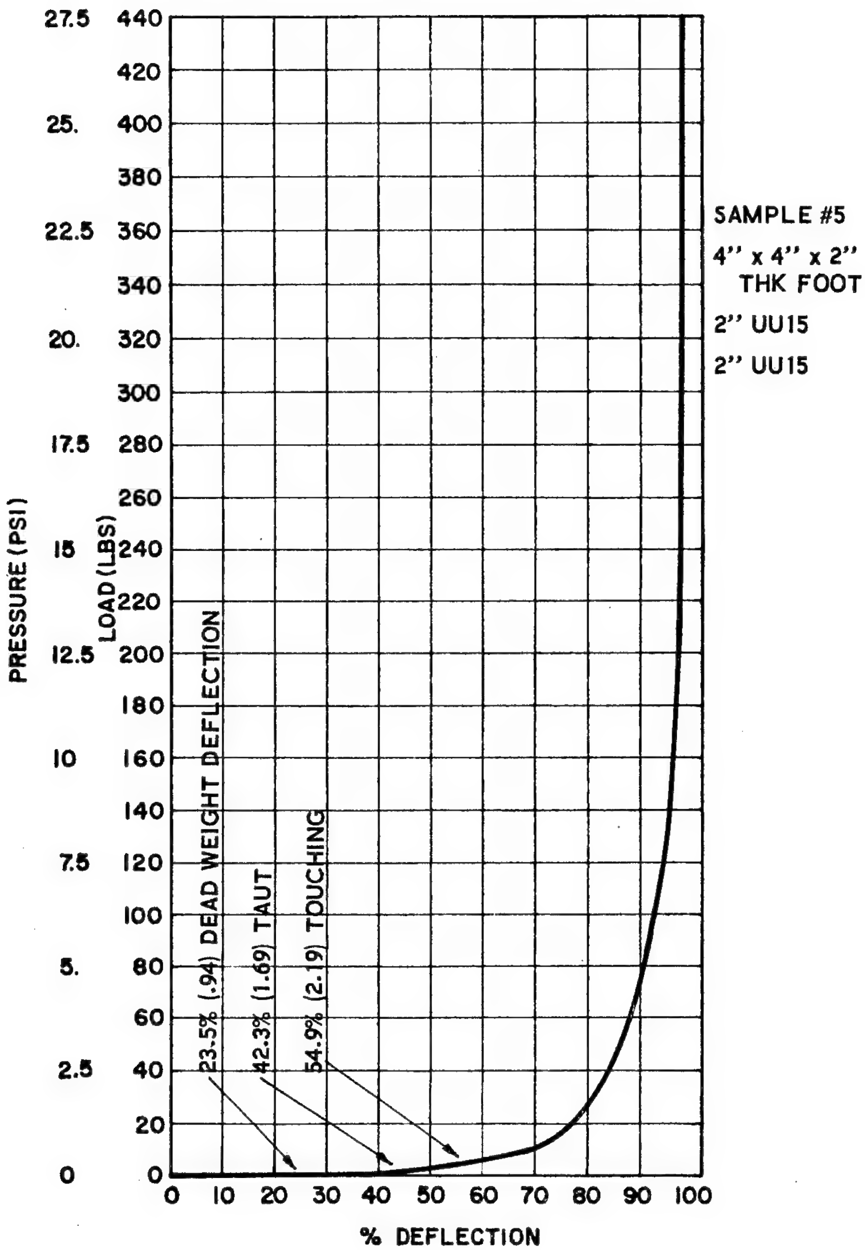
Foam Static Deflection Curve

Figure 7



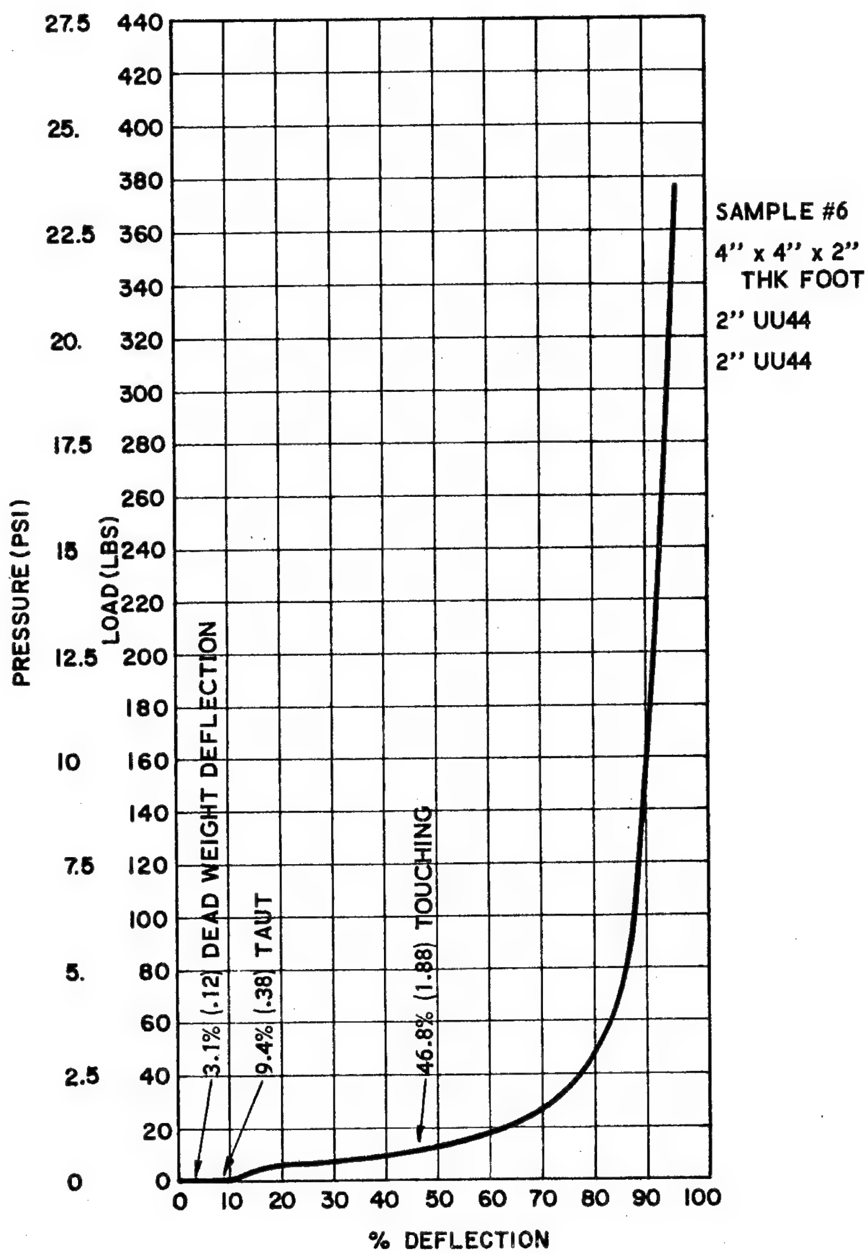
Foam Static Deflection Curve

Figure 8



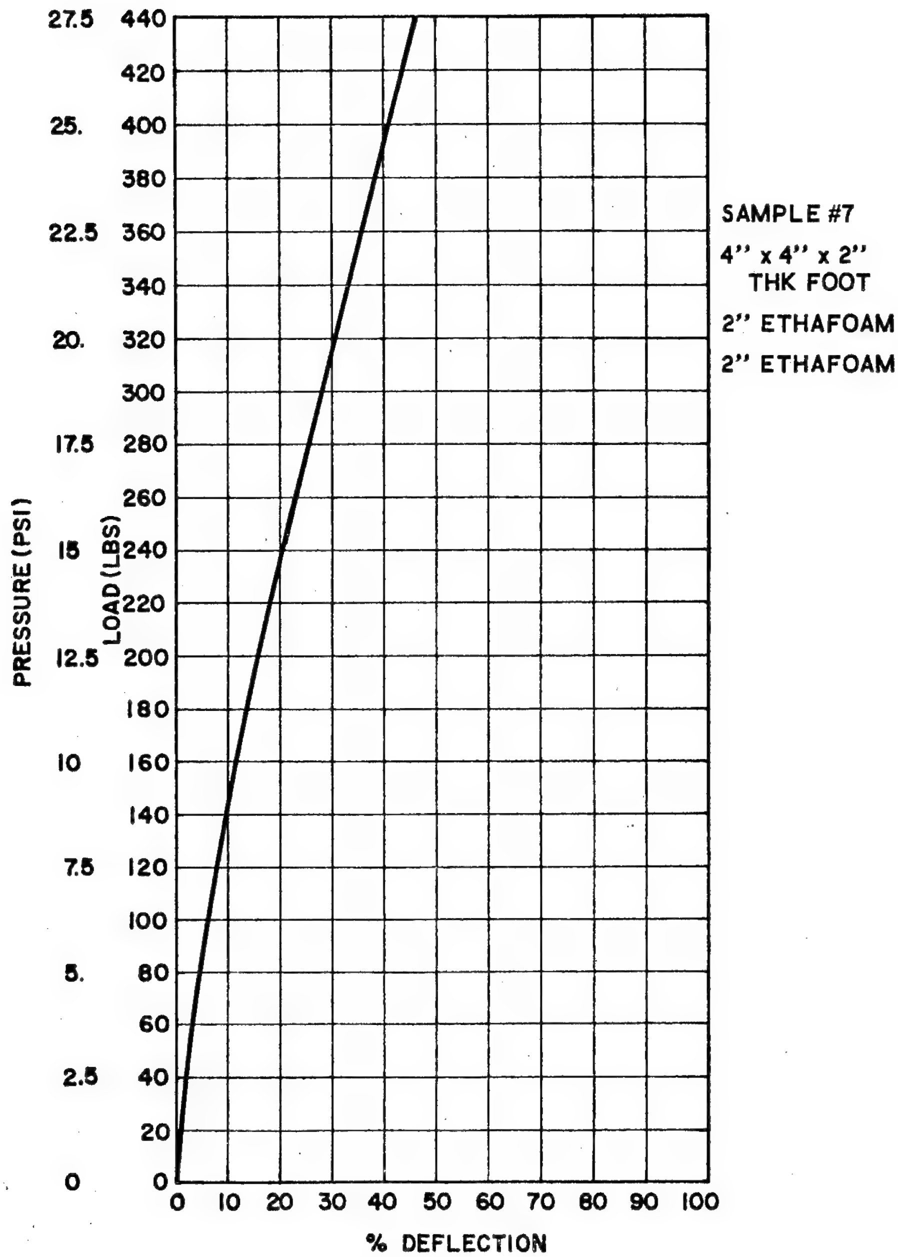
Foam Static Deflection Curve

Figure 9



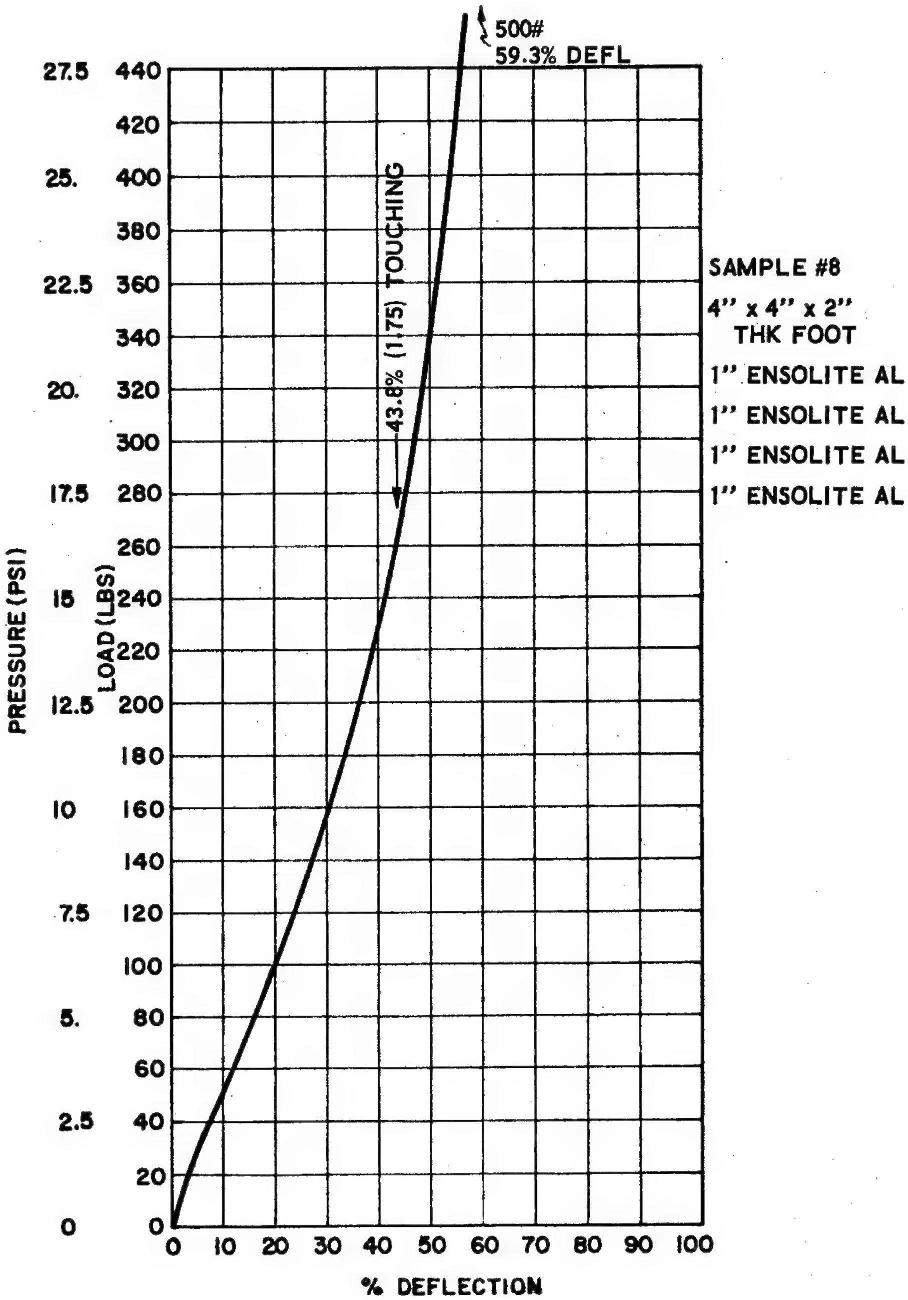
Foam Static Deflection Curve

Figure 10



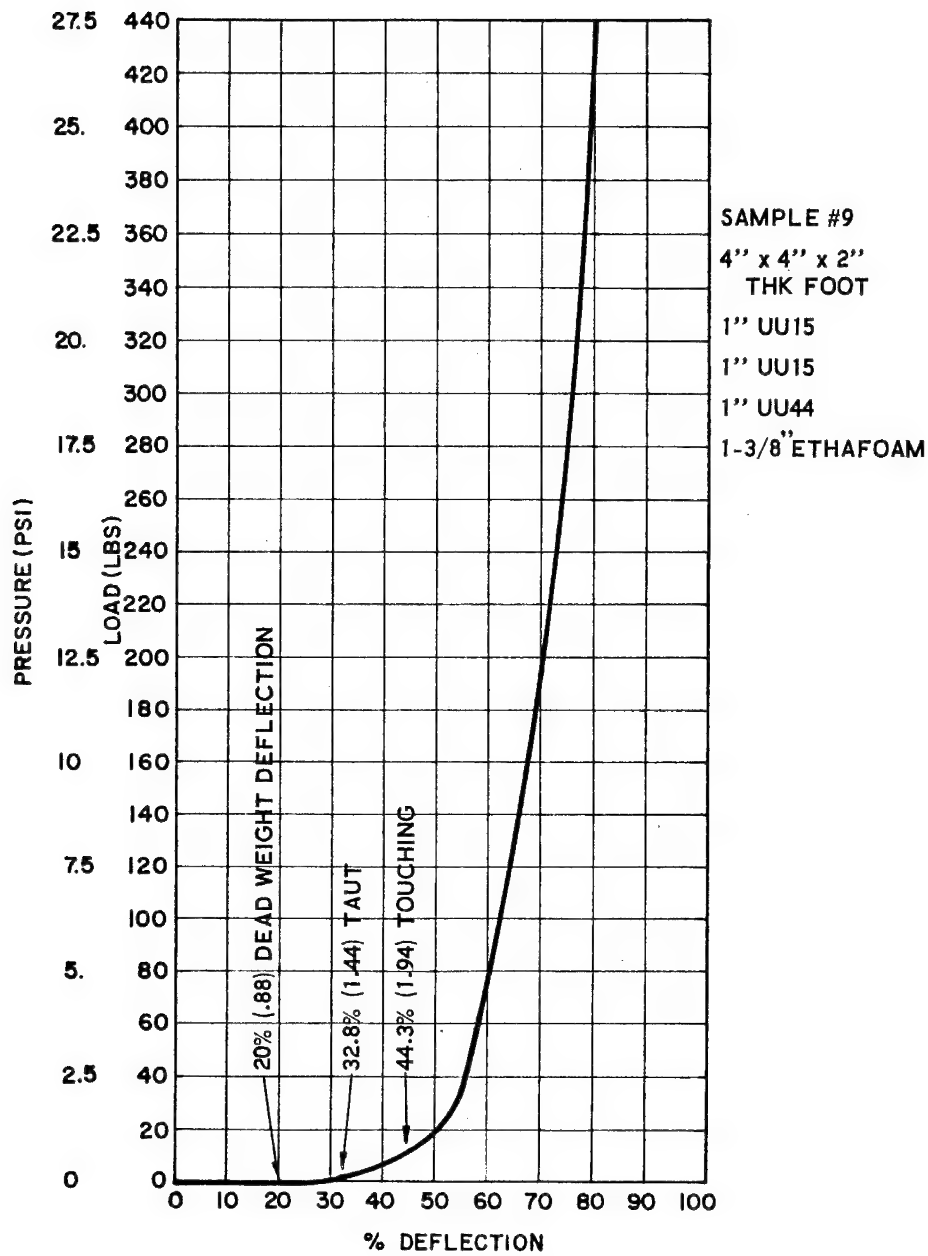
Foam Static Deflection Curve

Figure 11



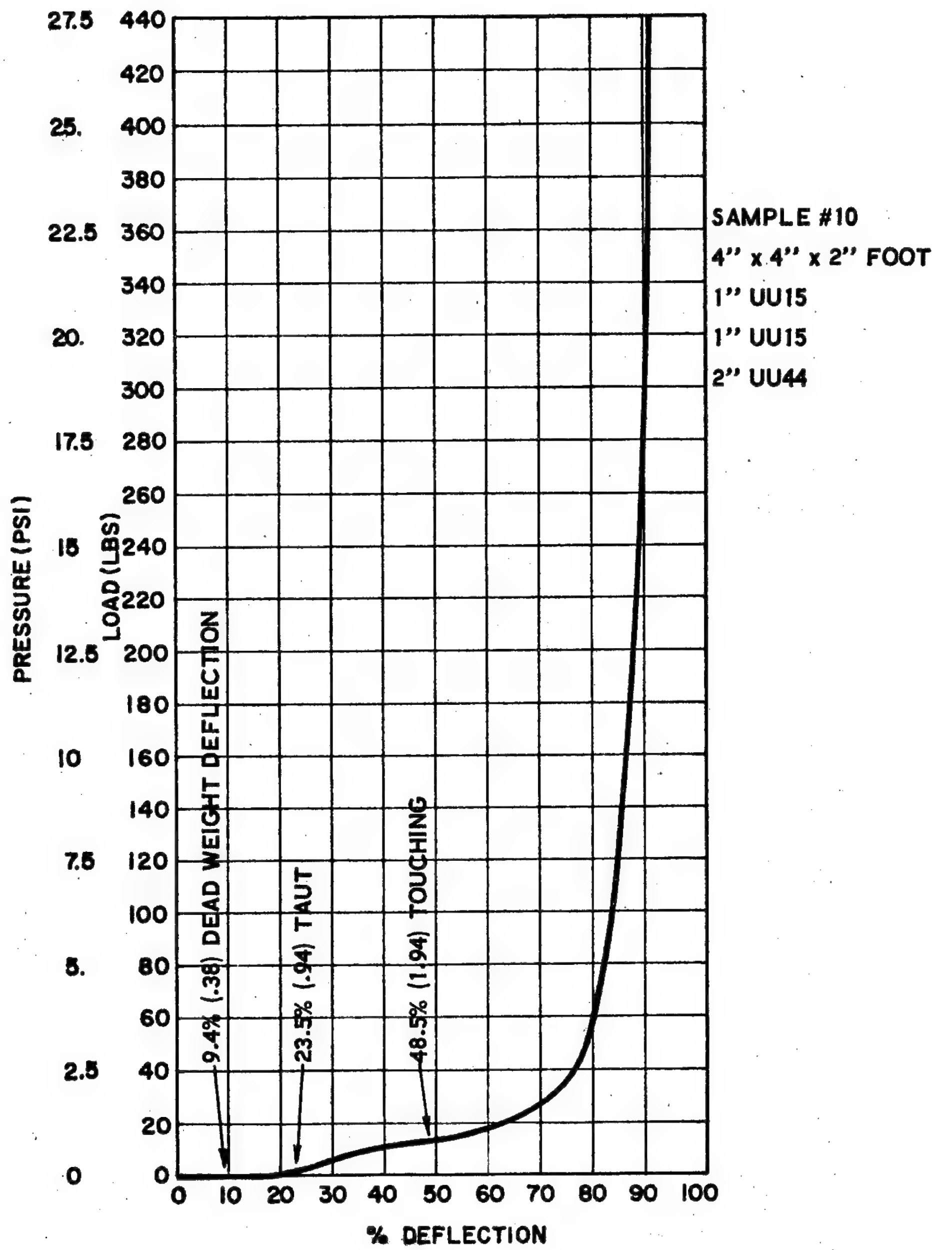
Foam Static Deflection Curve

Figure 12



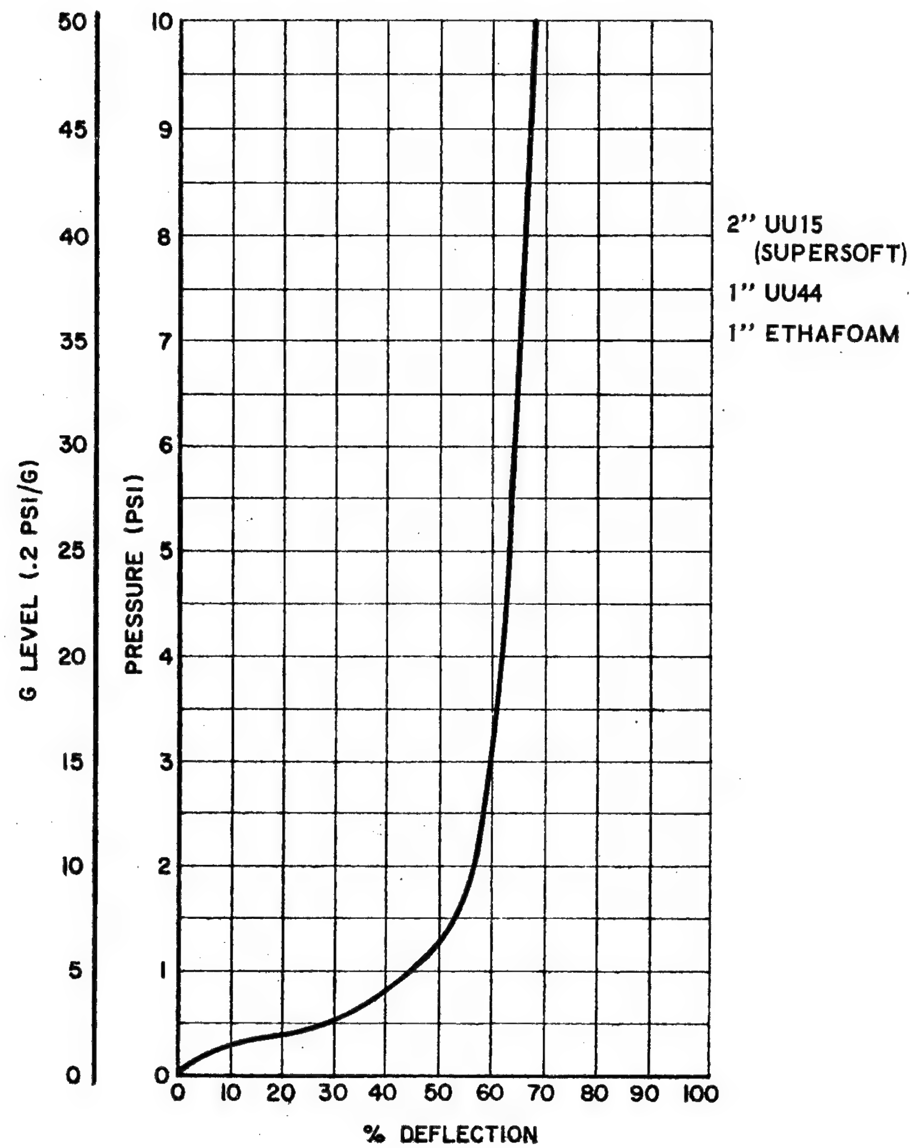
Foam Static Deflection Curve

Figure 13



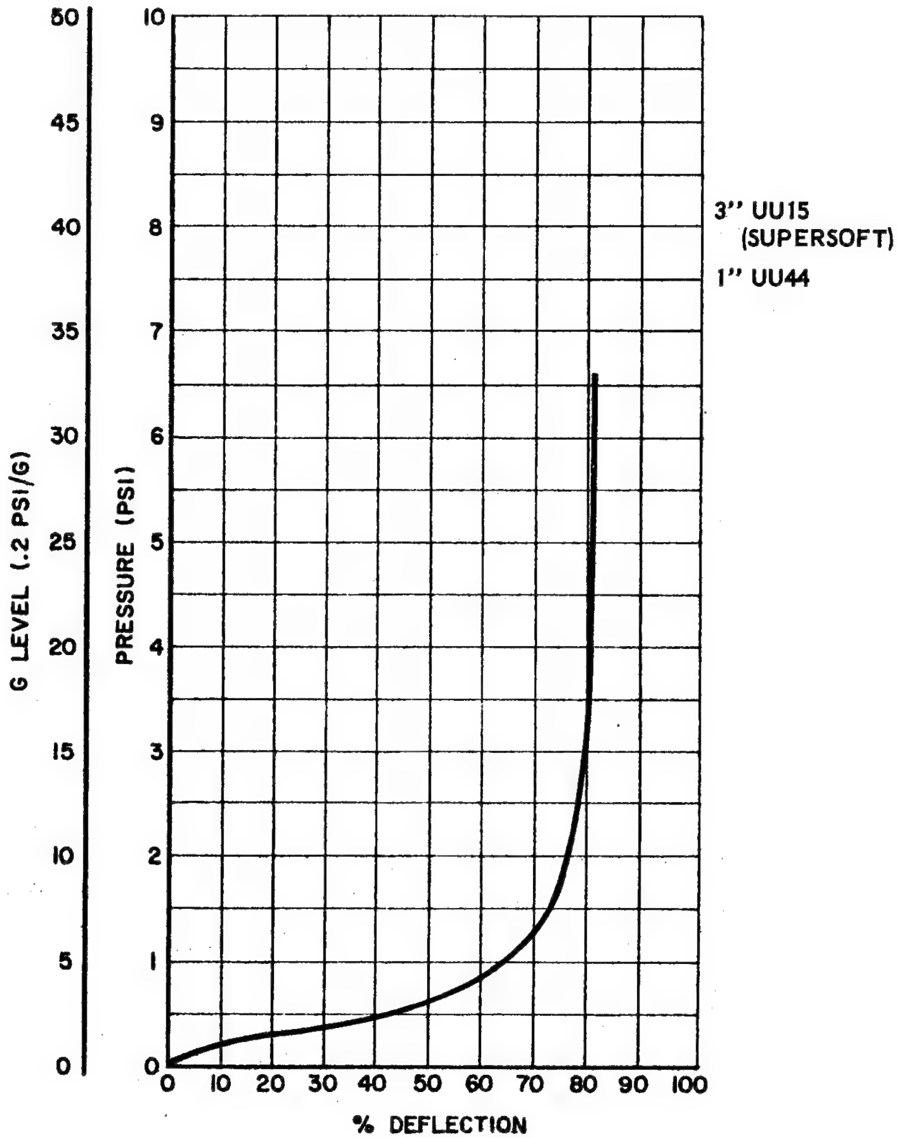
Foam Static Deflection Curve

Figure 14



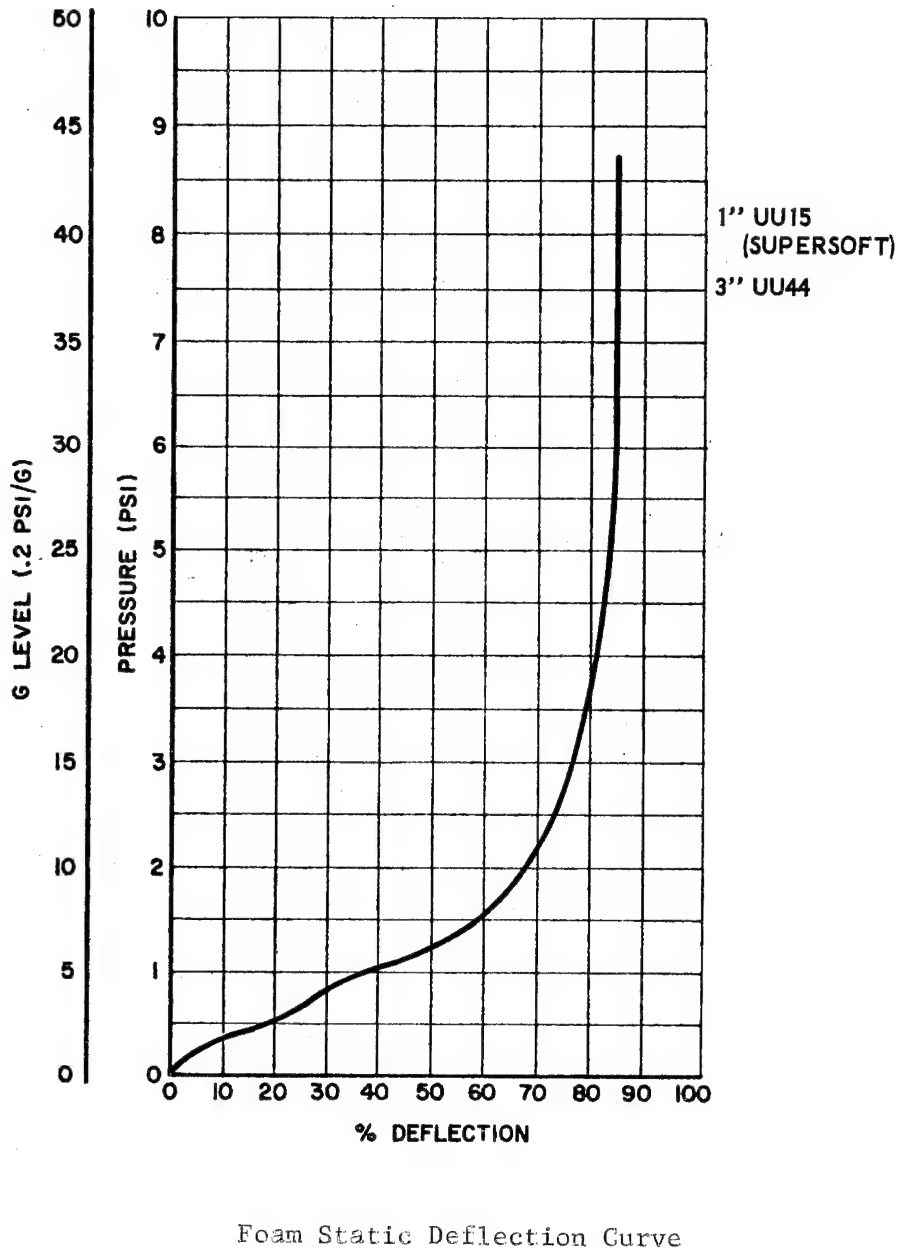
Foam Static Deflection Curve

Figure 15



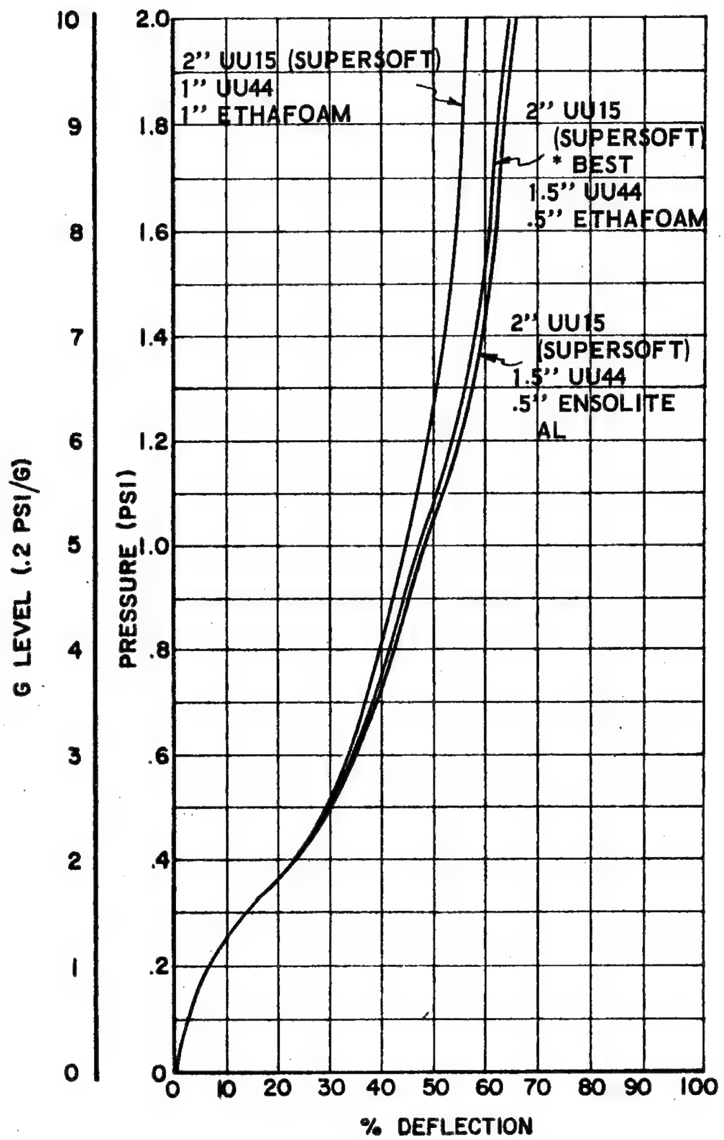
Foam Static Deflection Curve

Figure 16



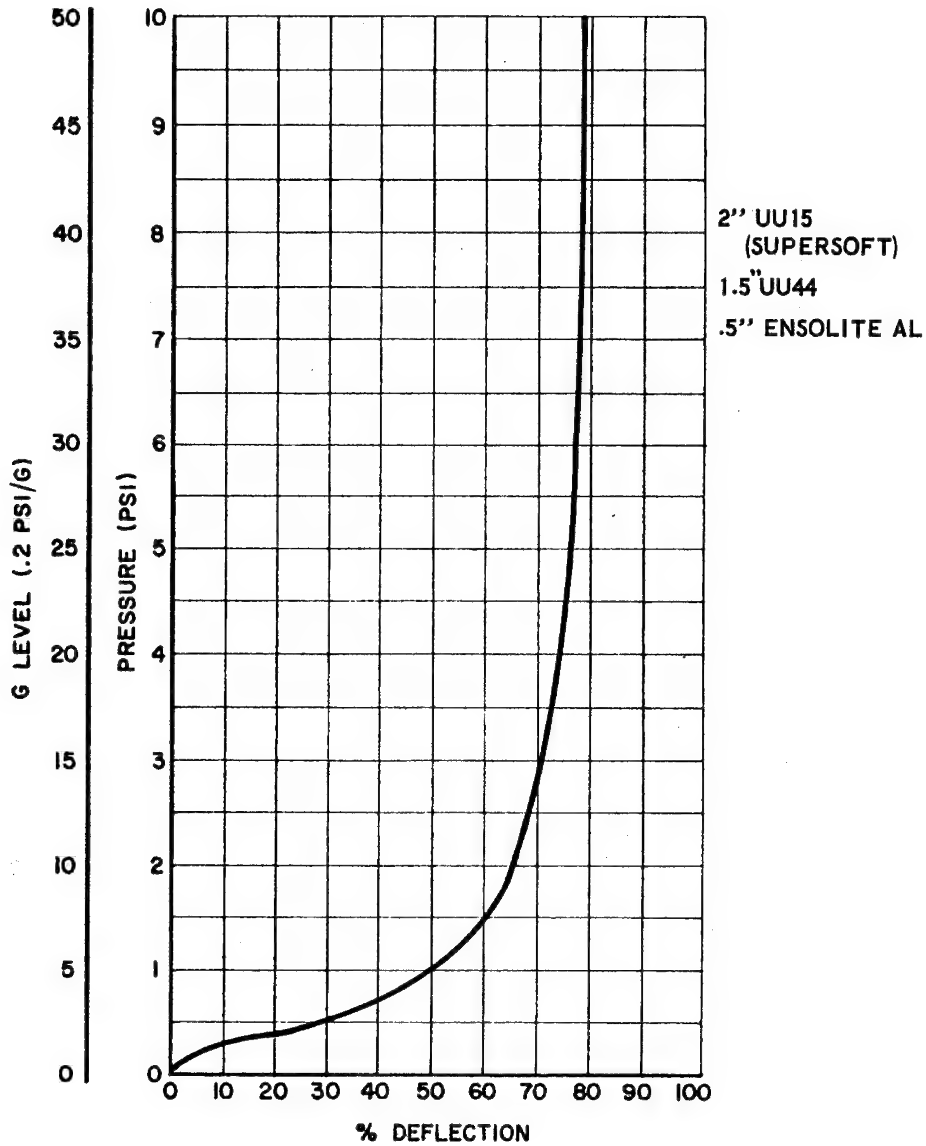
Foam Static Deflection Curve

Figure 17



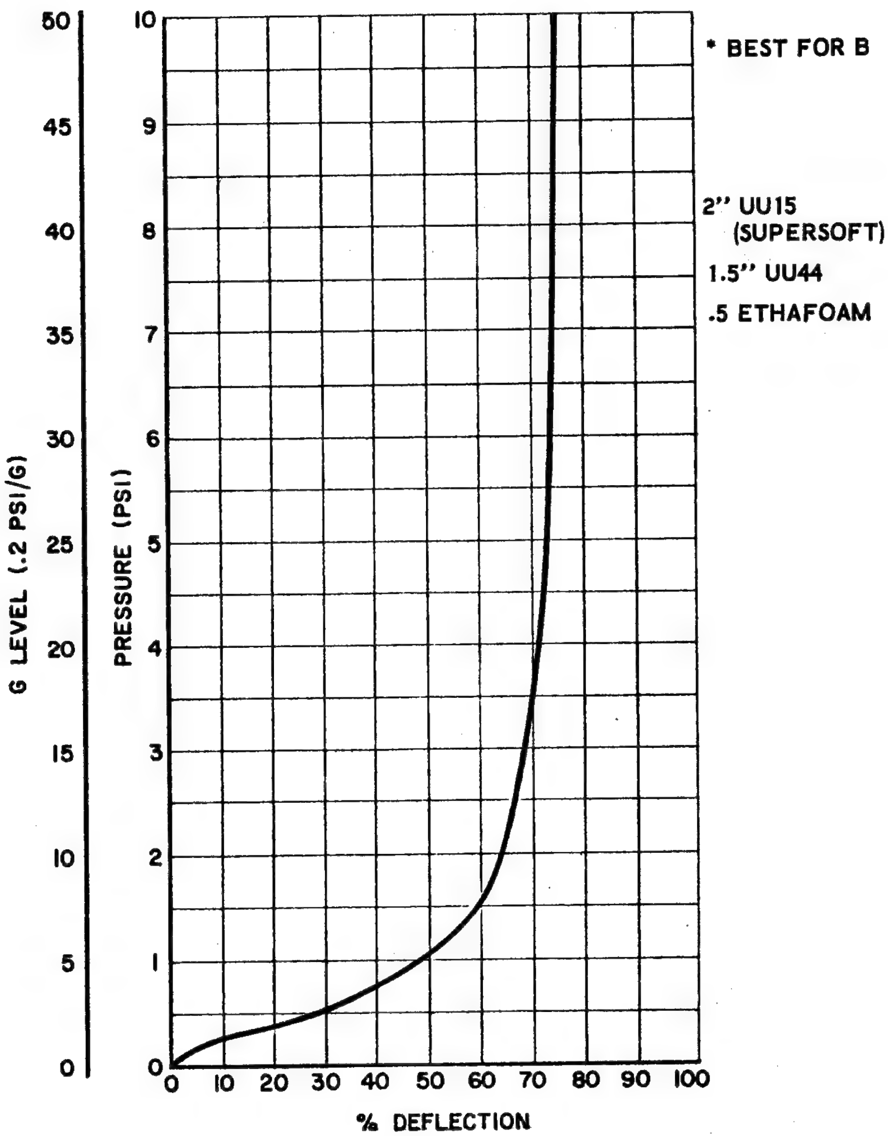
Foam Static Deflection Curve

Figure 18



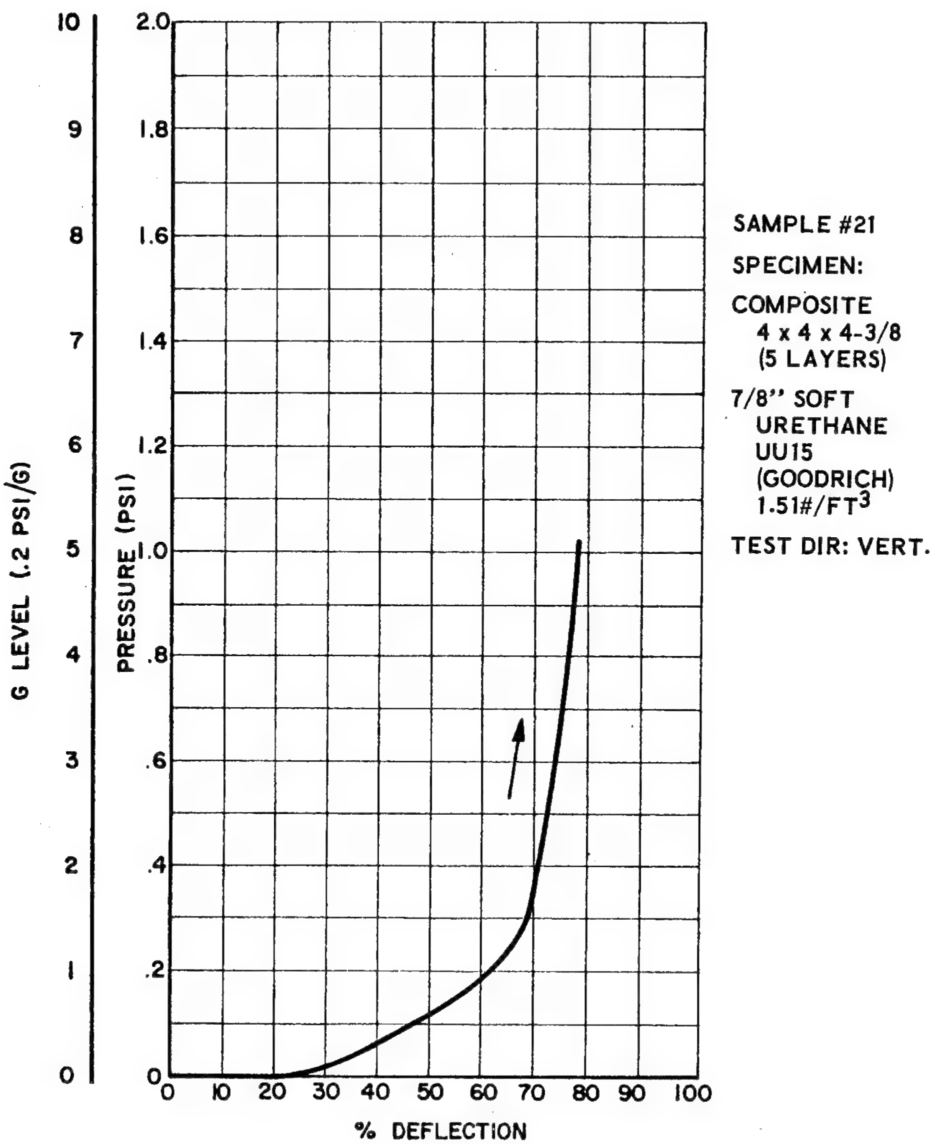
Foam Static Deflection Curve

Figure 19



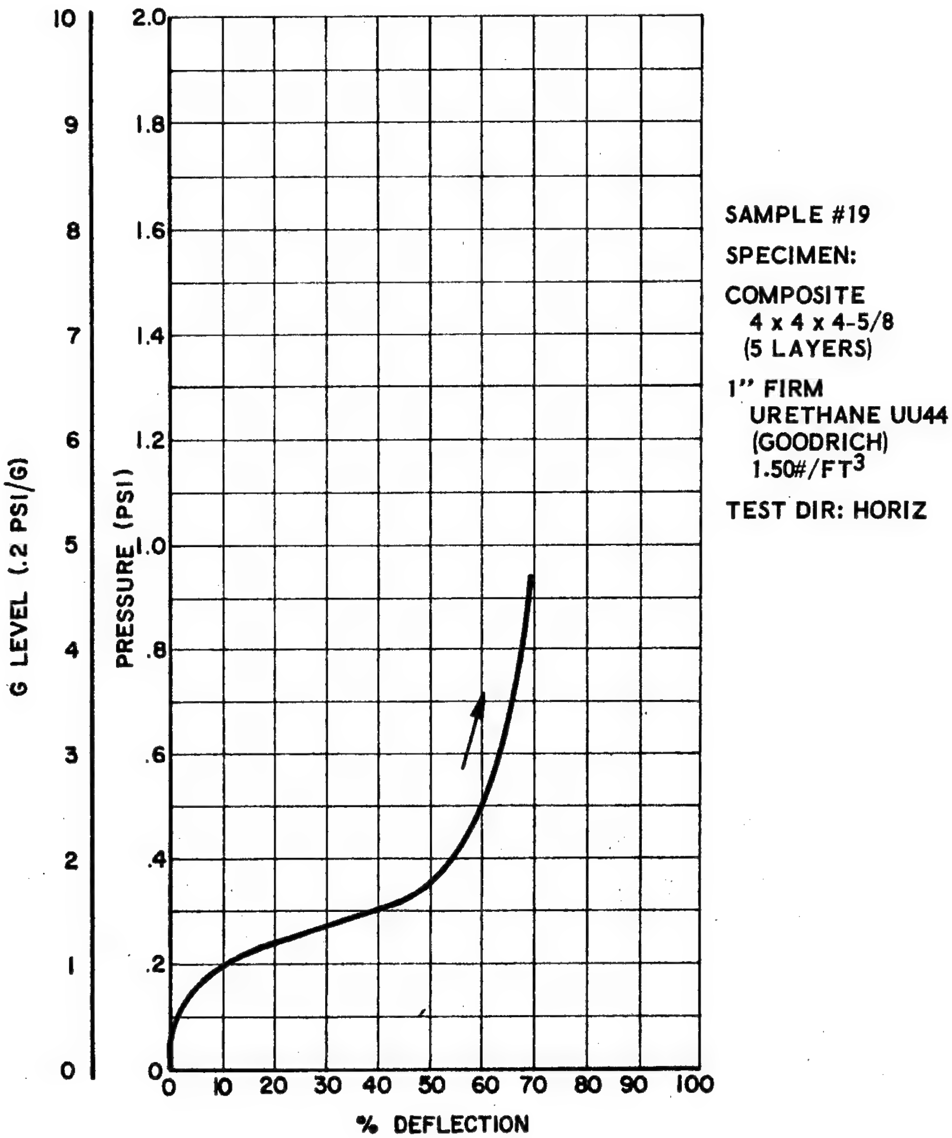
Foam Static Deflection Curve

Figure 20



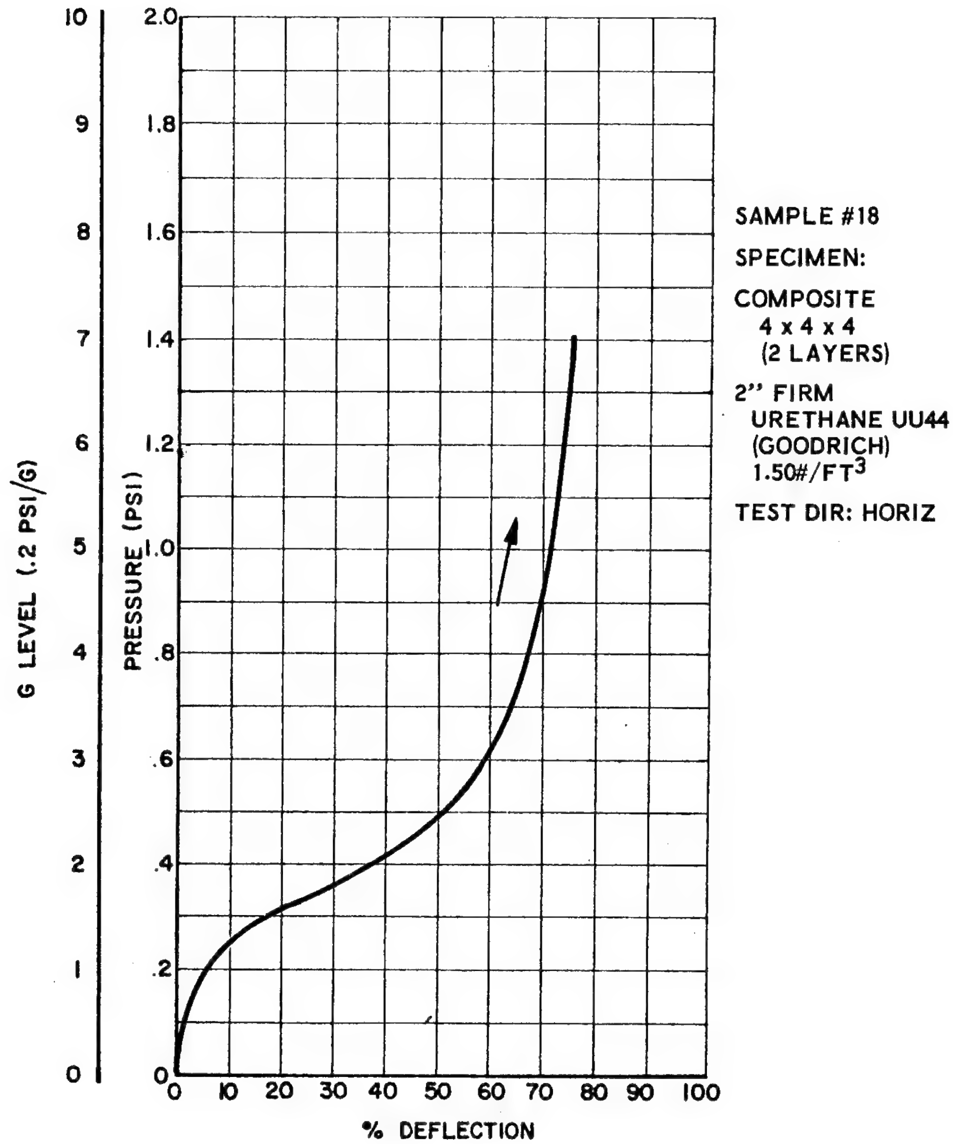
Foam Static Deflection Curve

Figure 21



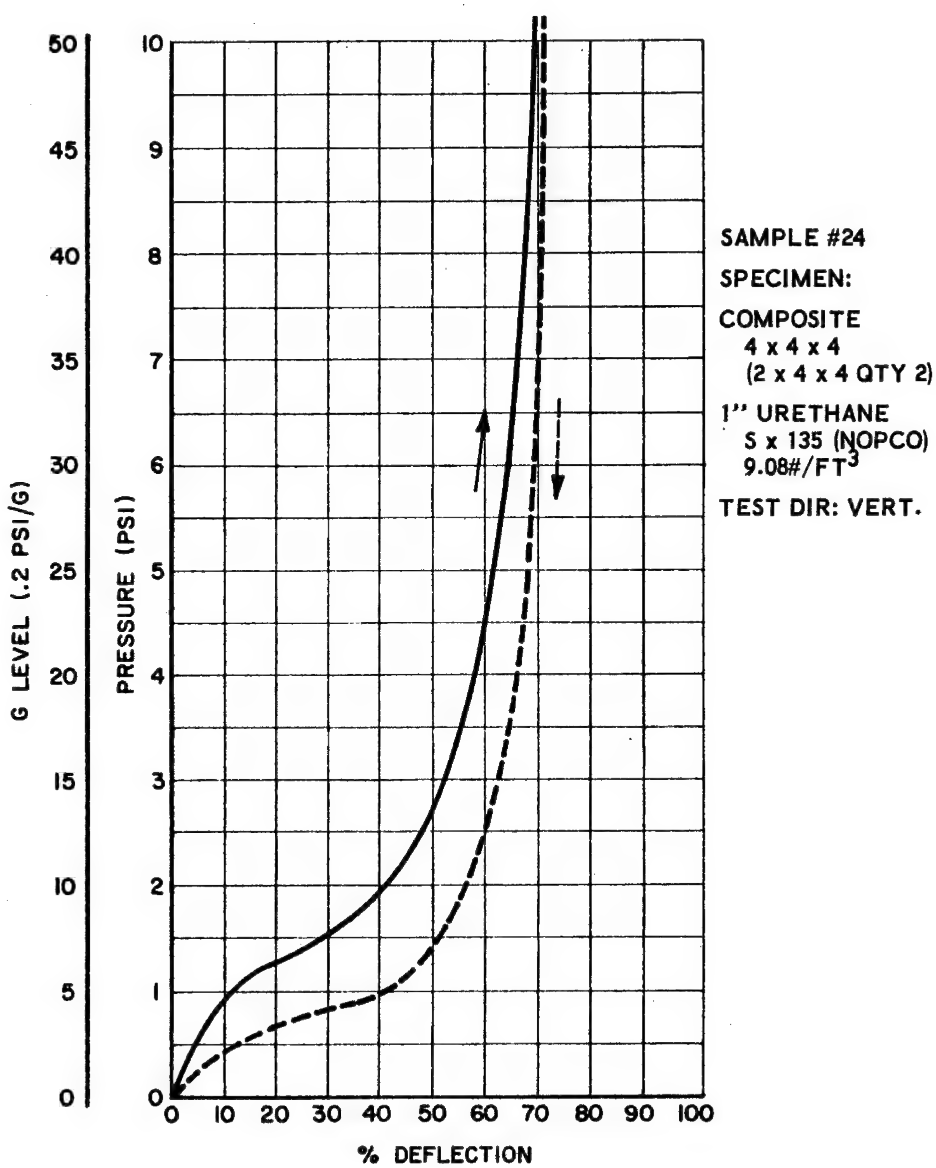
Foam Static Deflection Curve

Figure 22



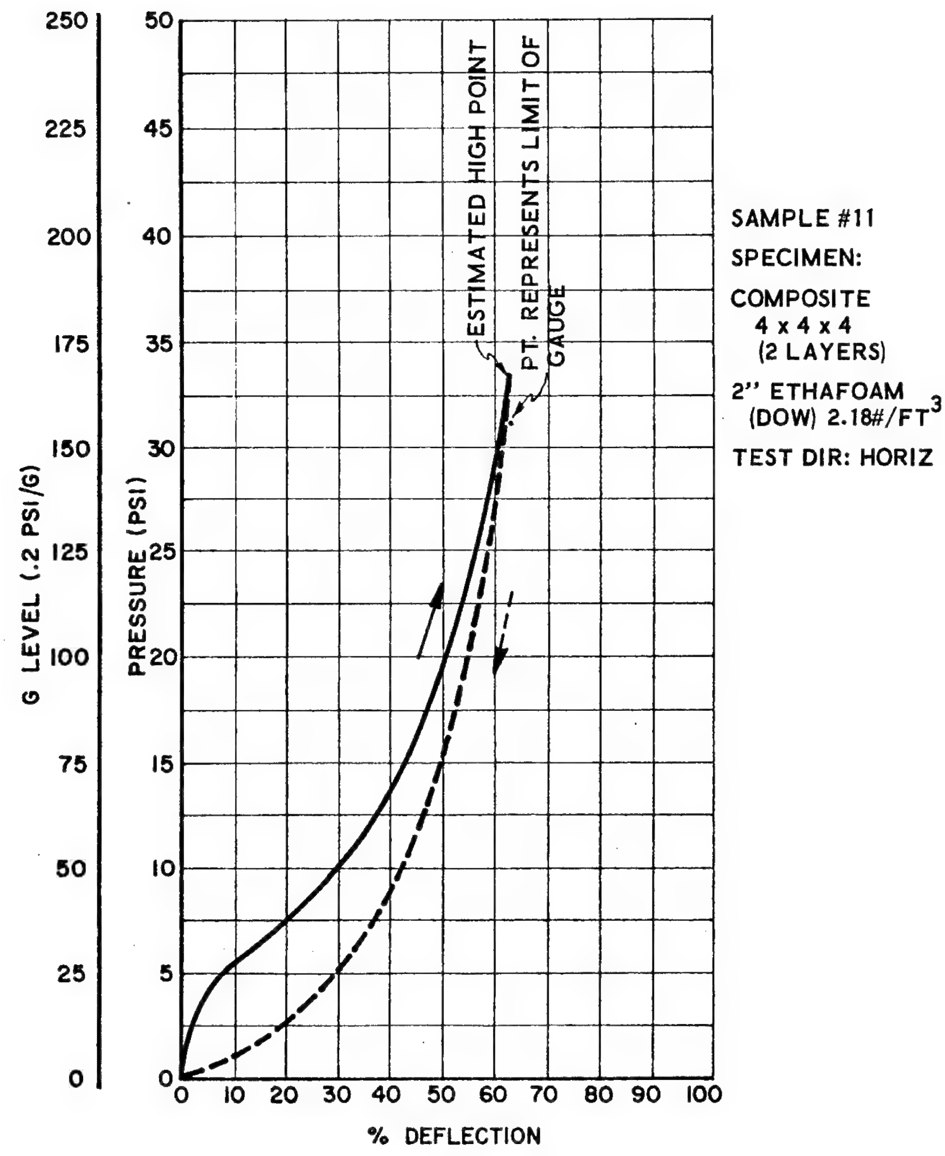
Foam Static Deflection Curve

Figure 23



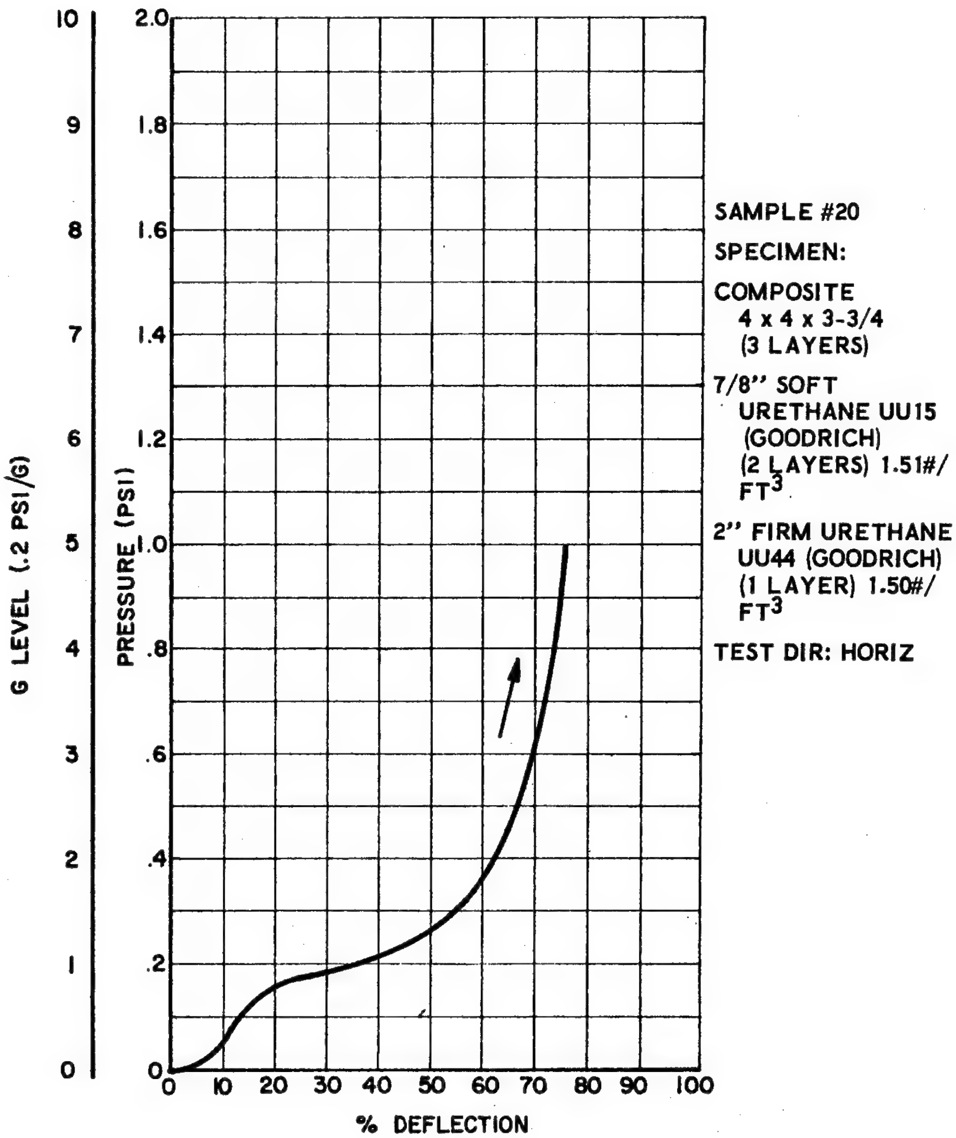
Foam Static Deflection Curve

Figure 24



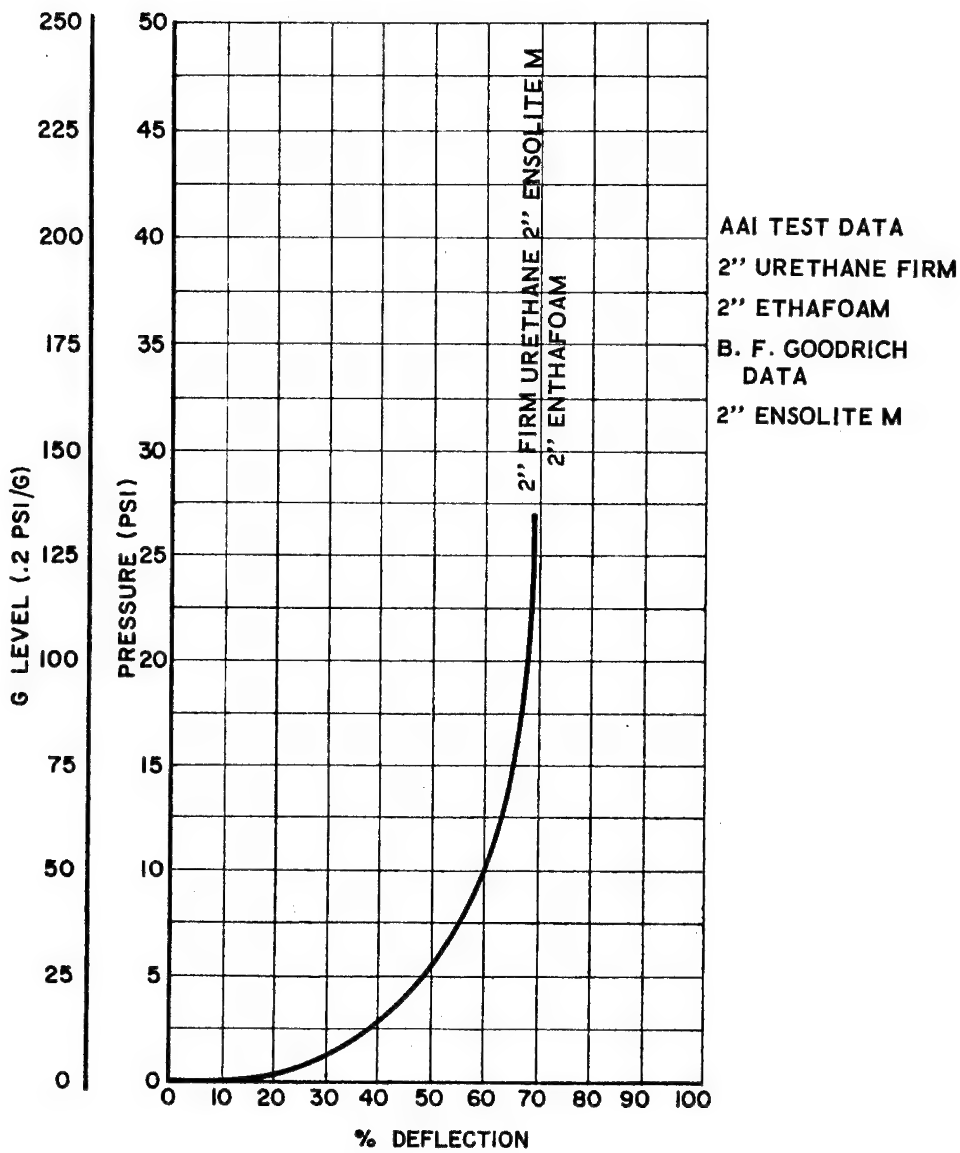
Foam Static Deflection Curve

Figure 25



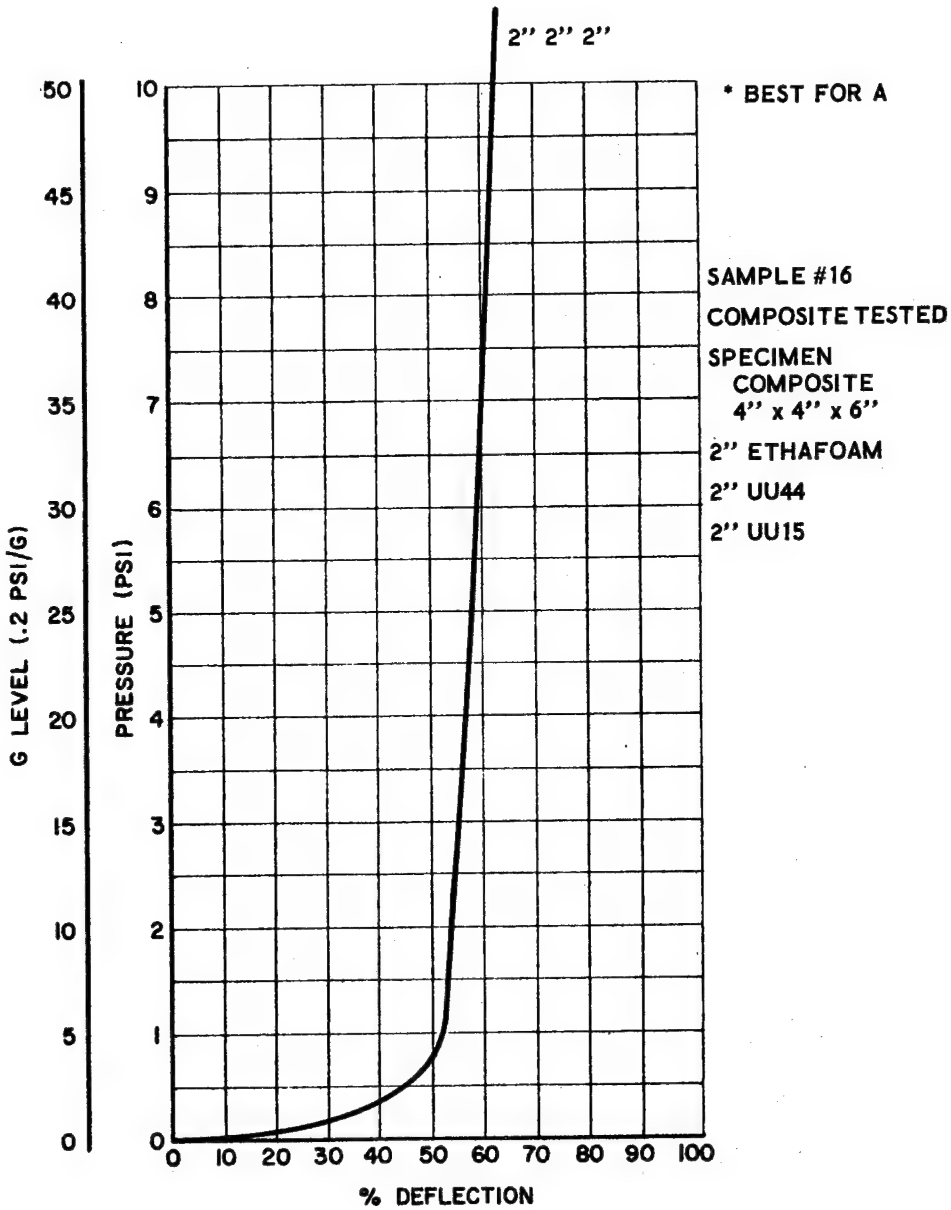
Foam Static Deflection Curve

Figure 26



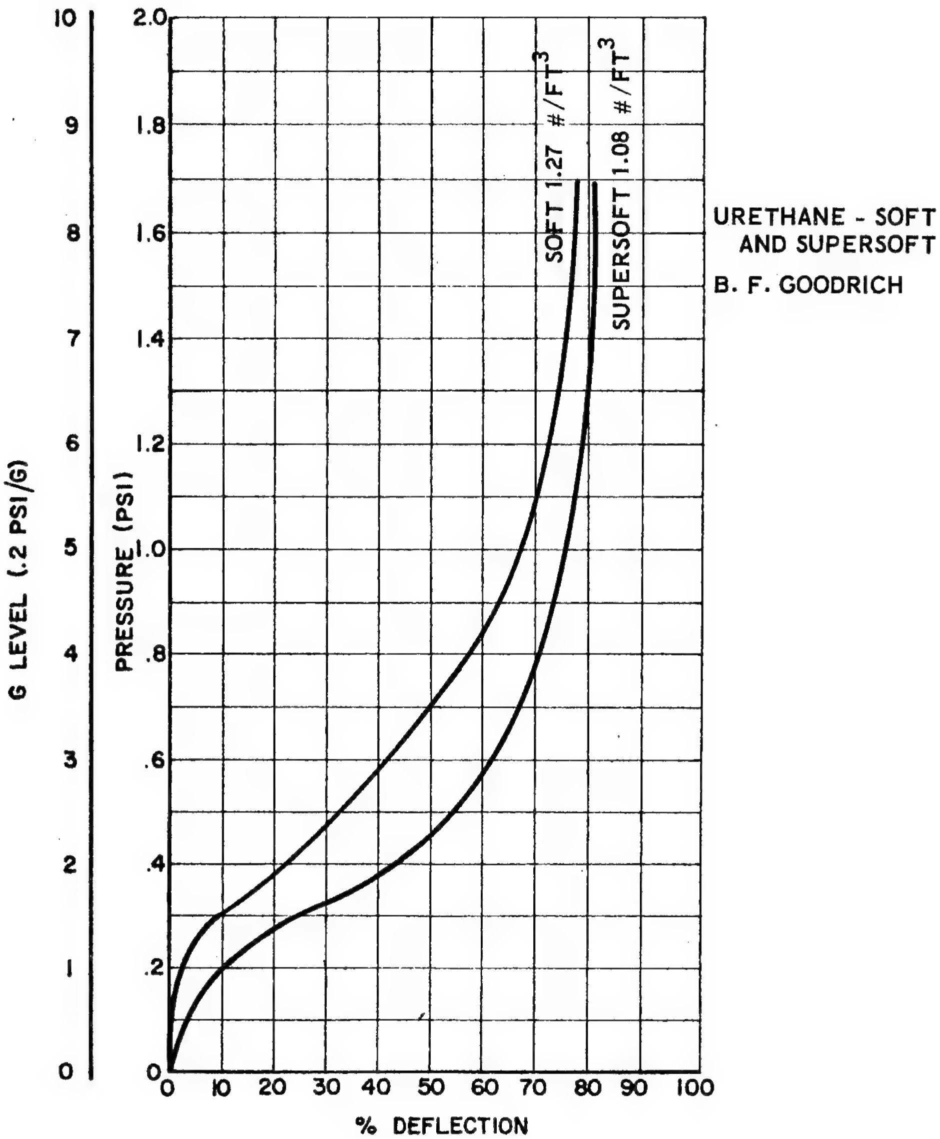
Foam Static Deflection Curve

Figure 27



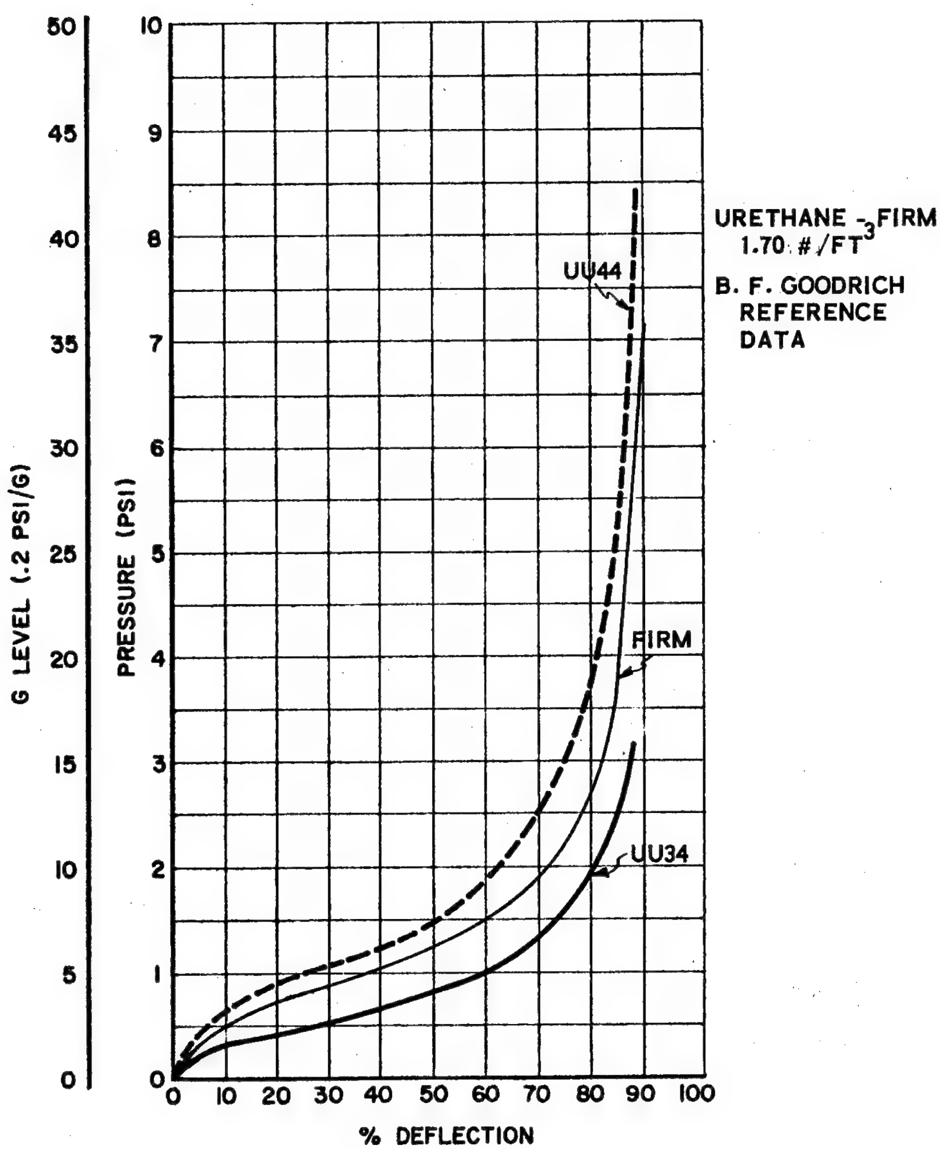
Foam Static Deflection Curve

Figure 28



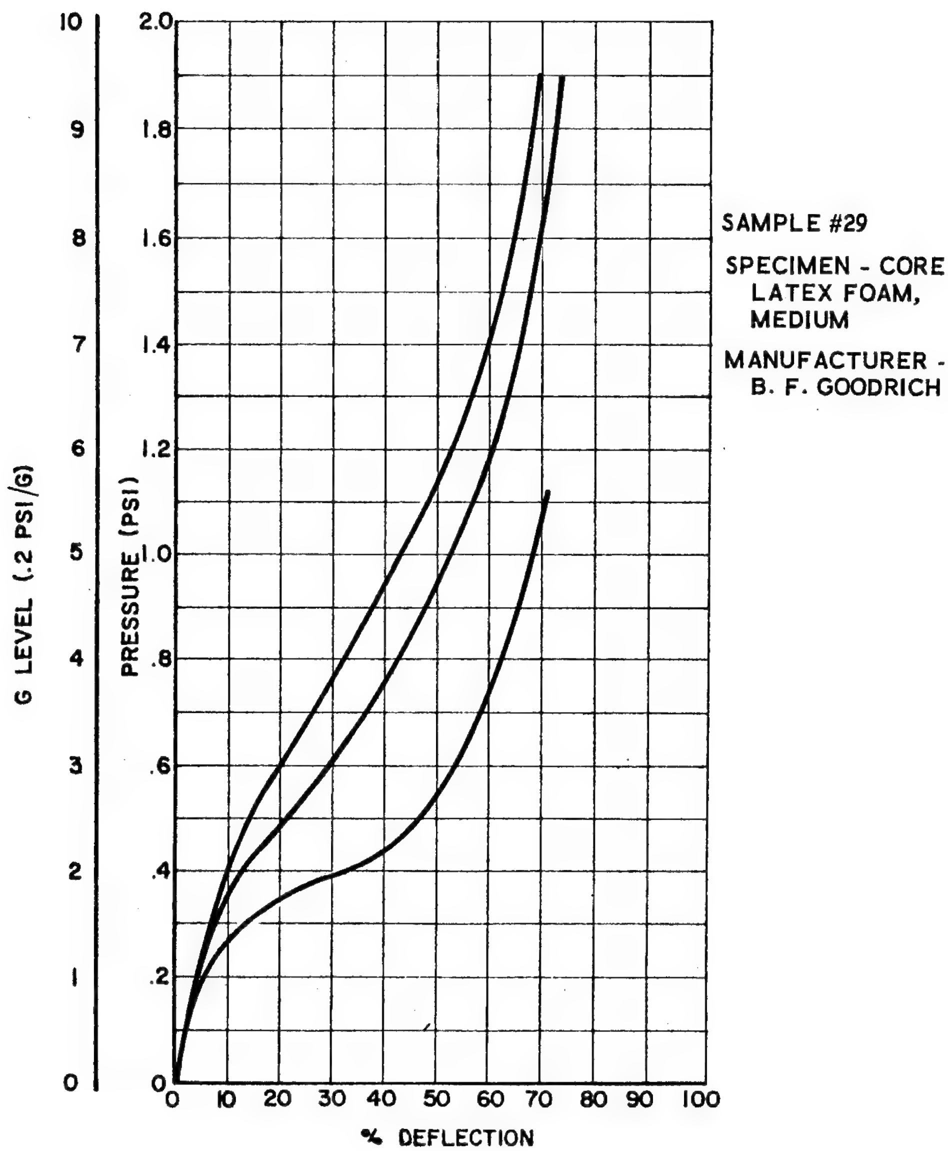
Foam Static Deflection Curve

Figure 29



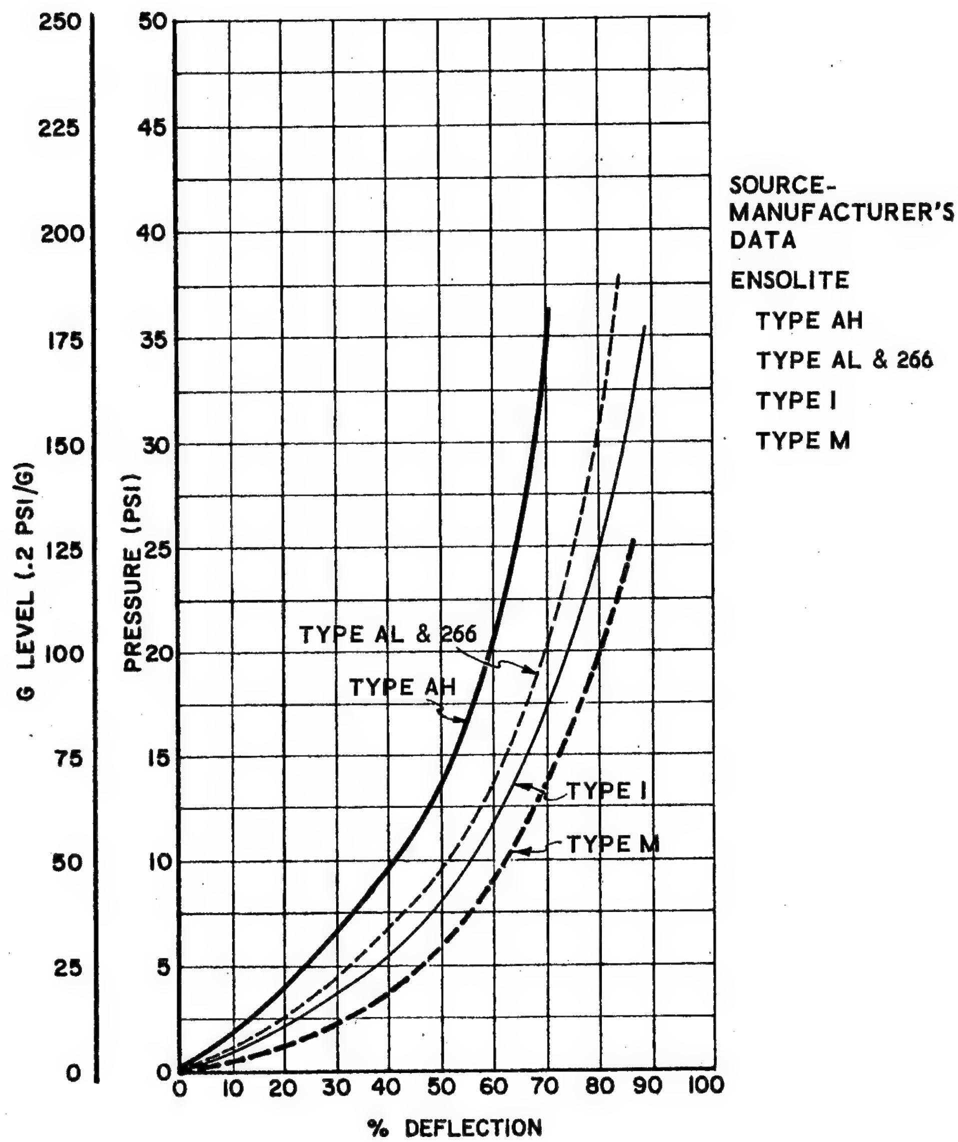
Foam Static Deflection Curve

Figure 30



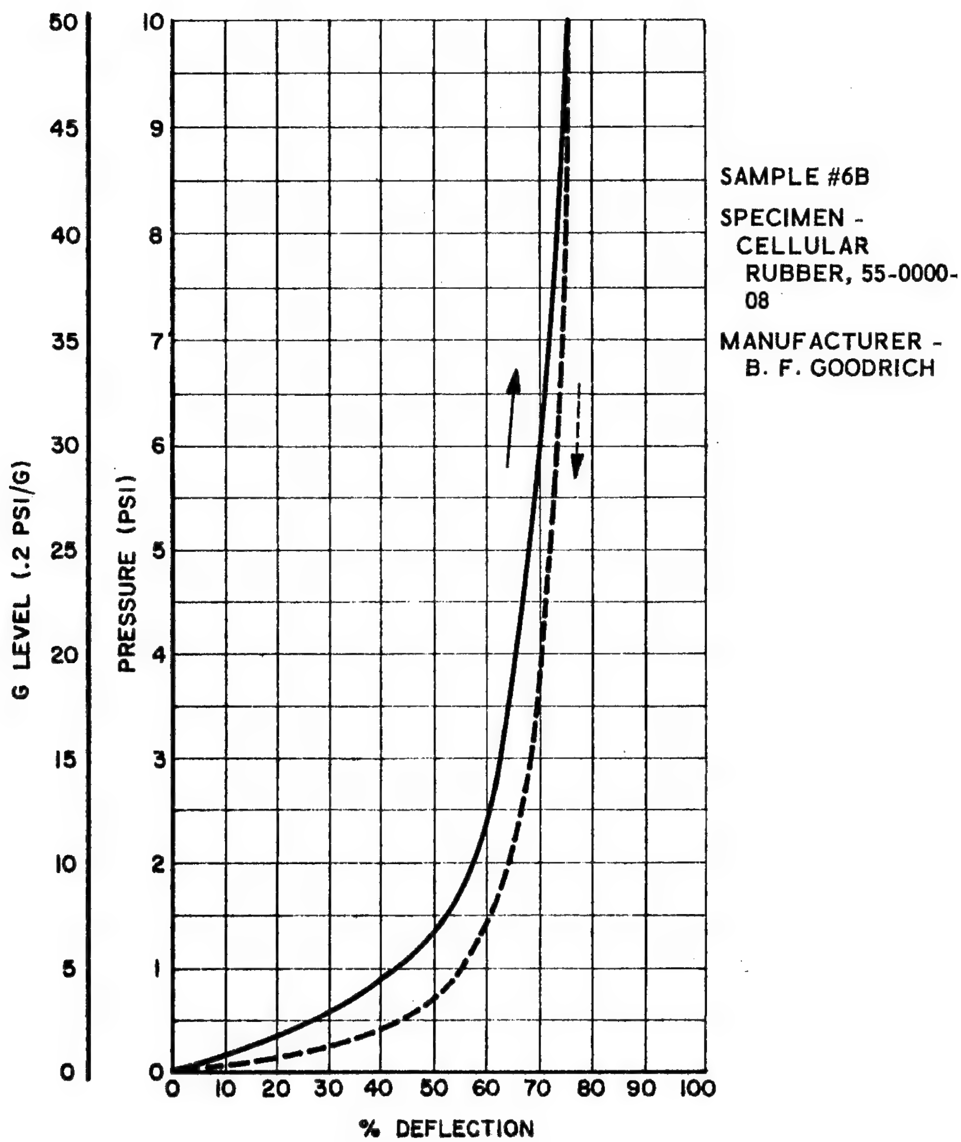
Foam Static Deflection Curve

Figure 31



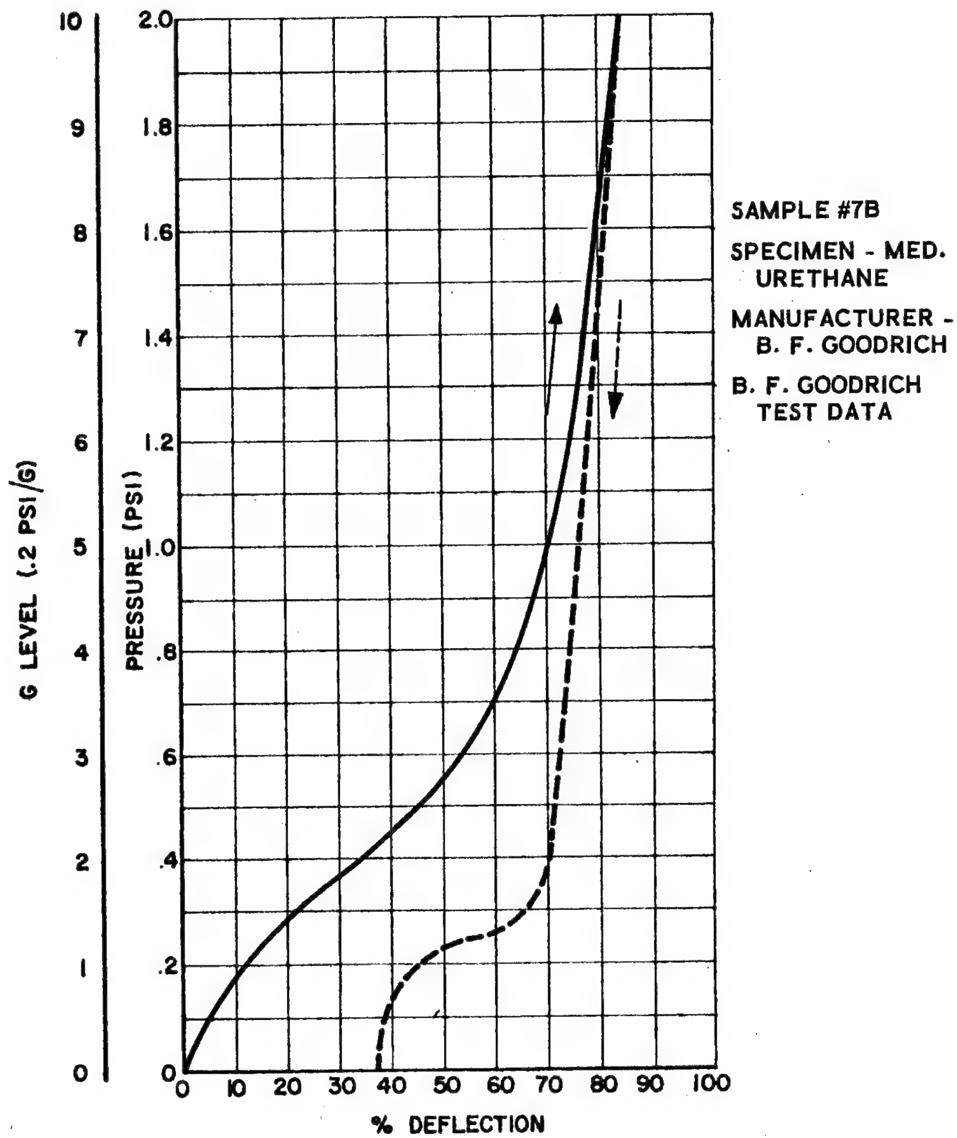
Foam Static Deflection Curve

Figure 32



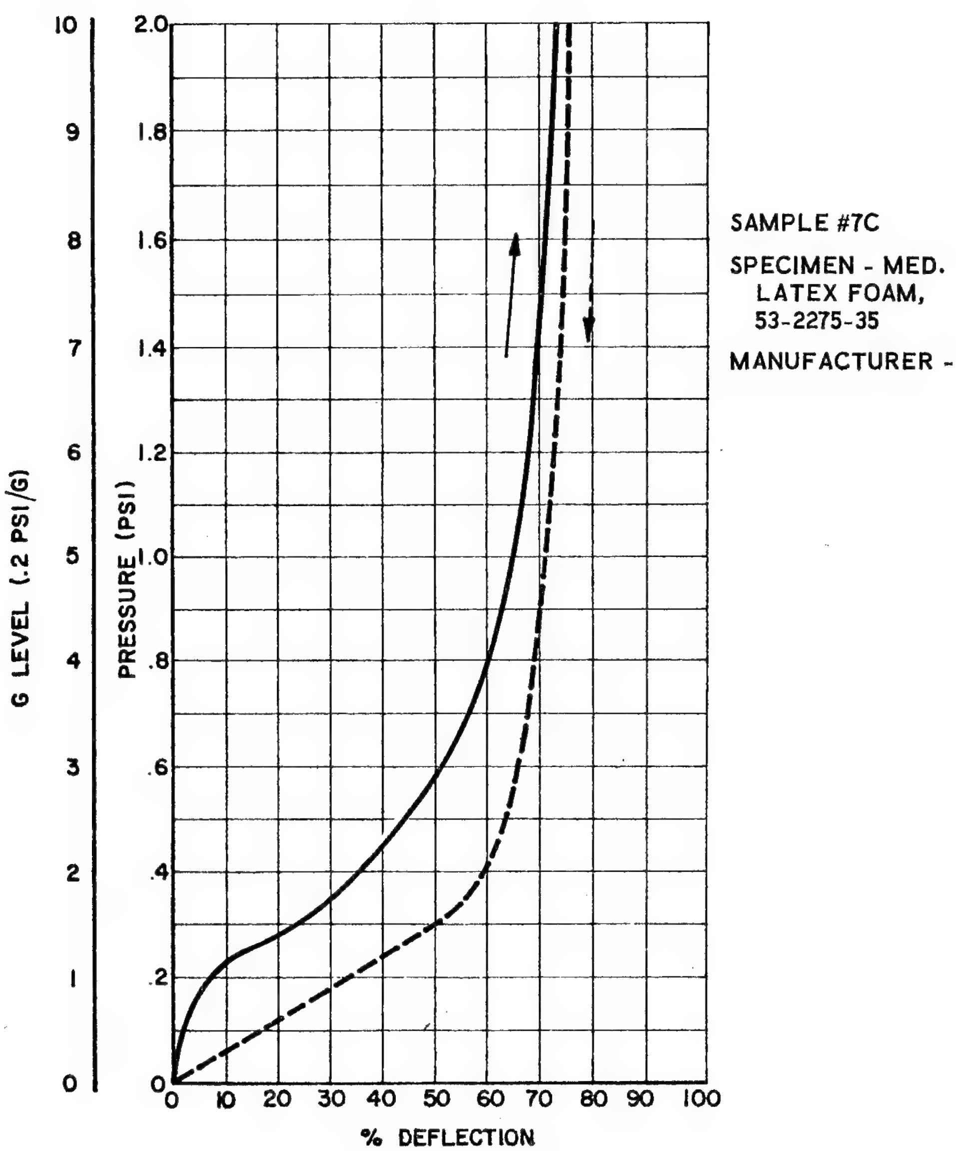
Foam Static Deflection Curve

Figure 33



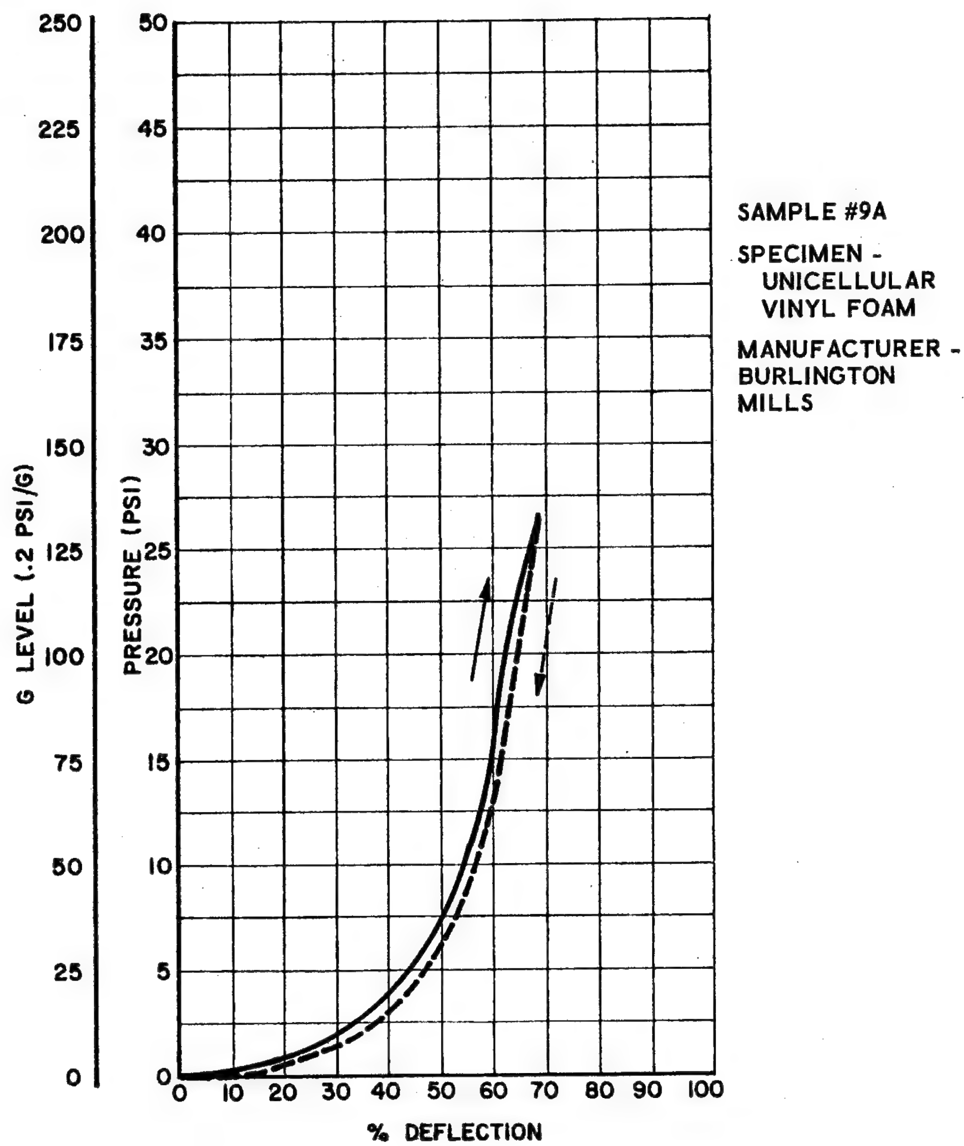
Foam Static Deflection Curve

Figure 34



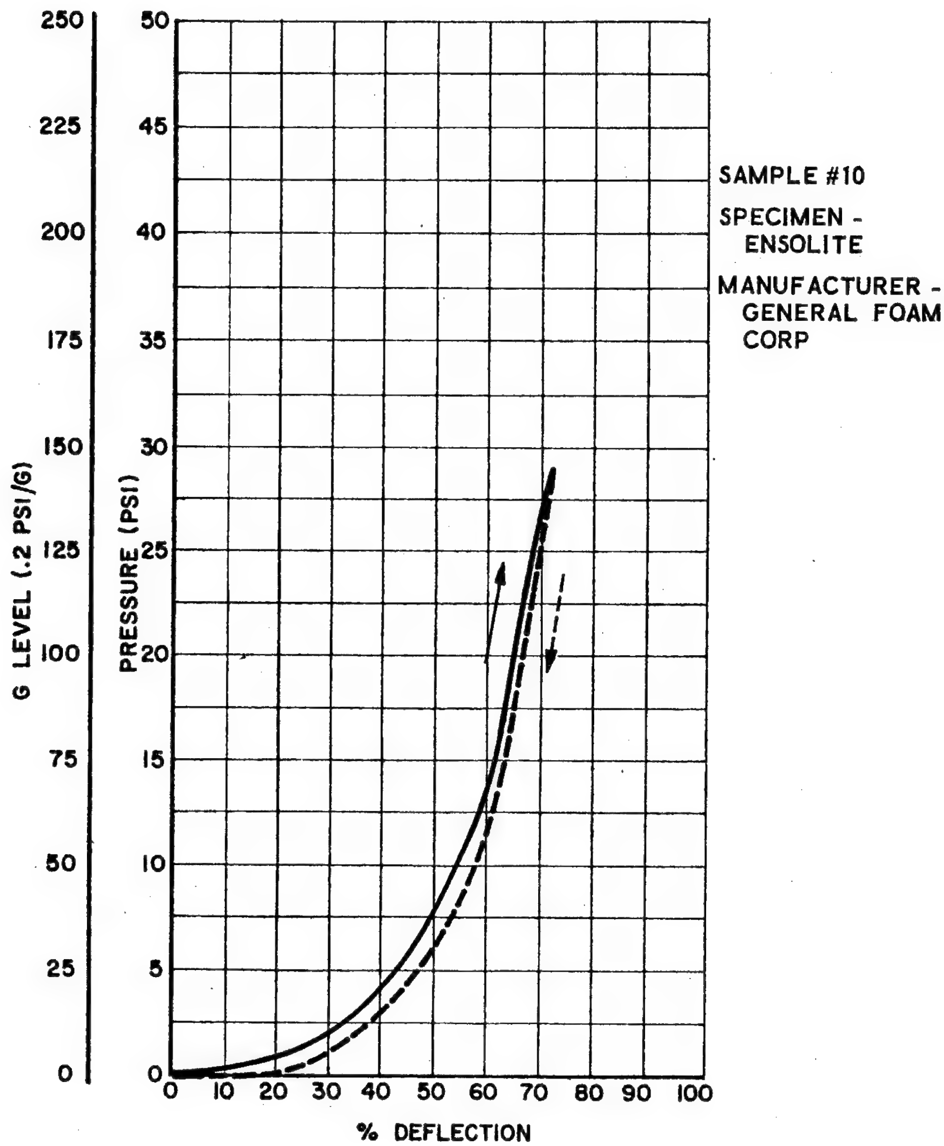
Foam Static Deflection Curve

Figure 35



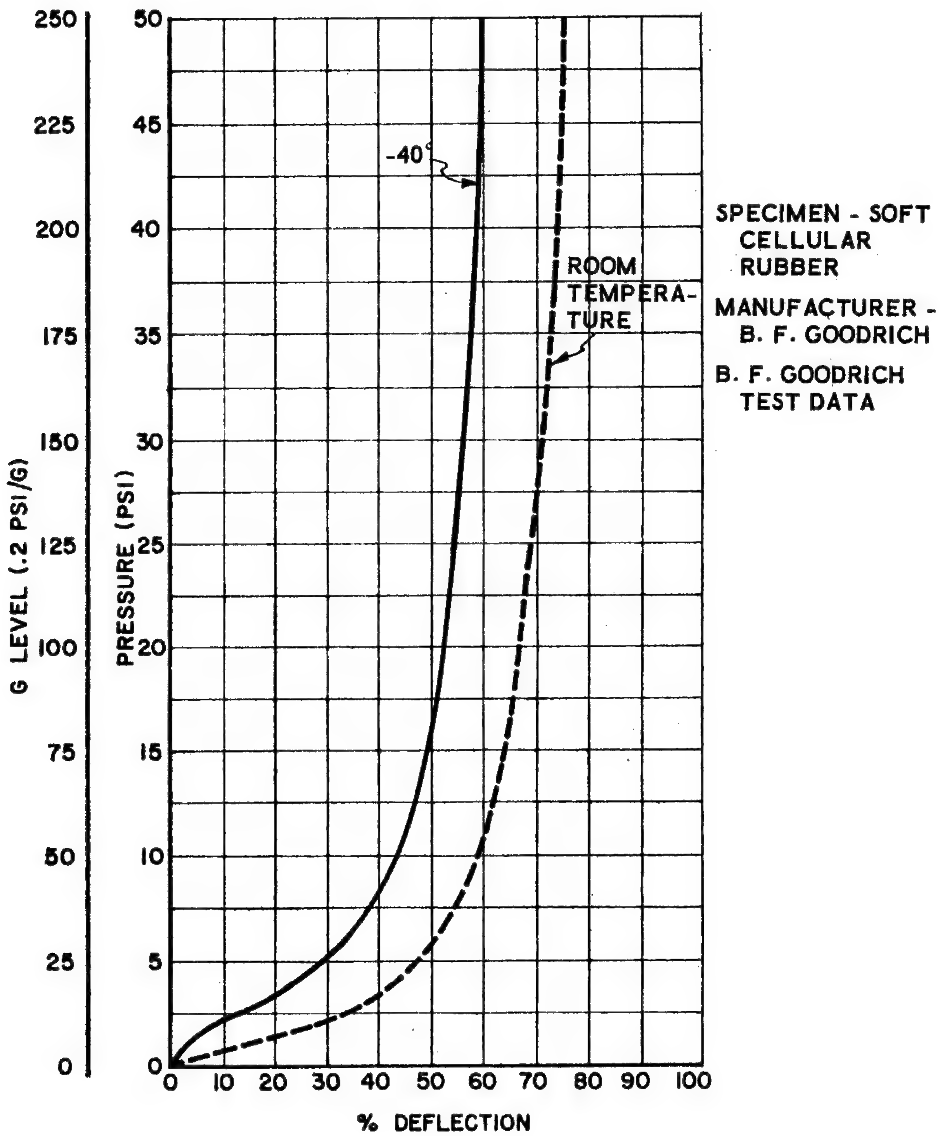
Foam Static Deflection Curve

Figure 36



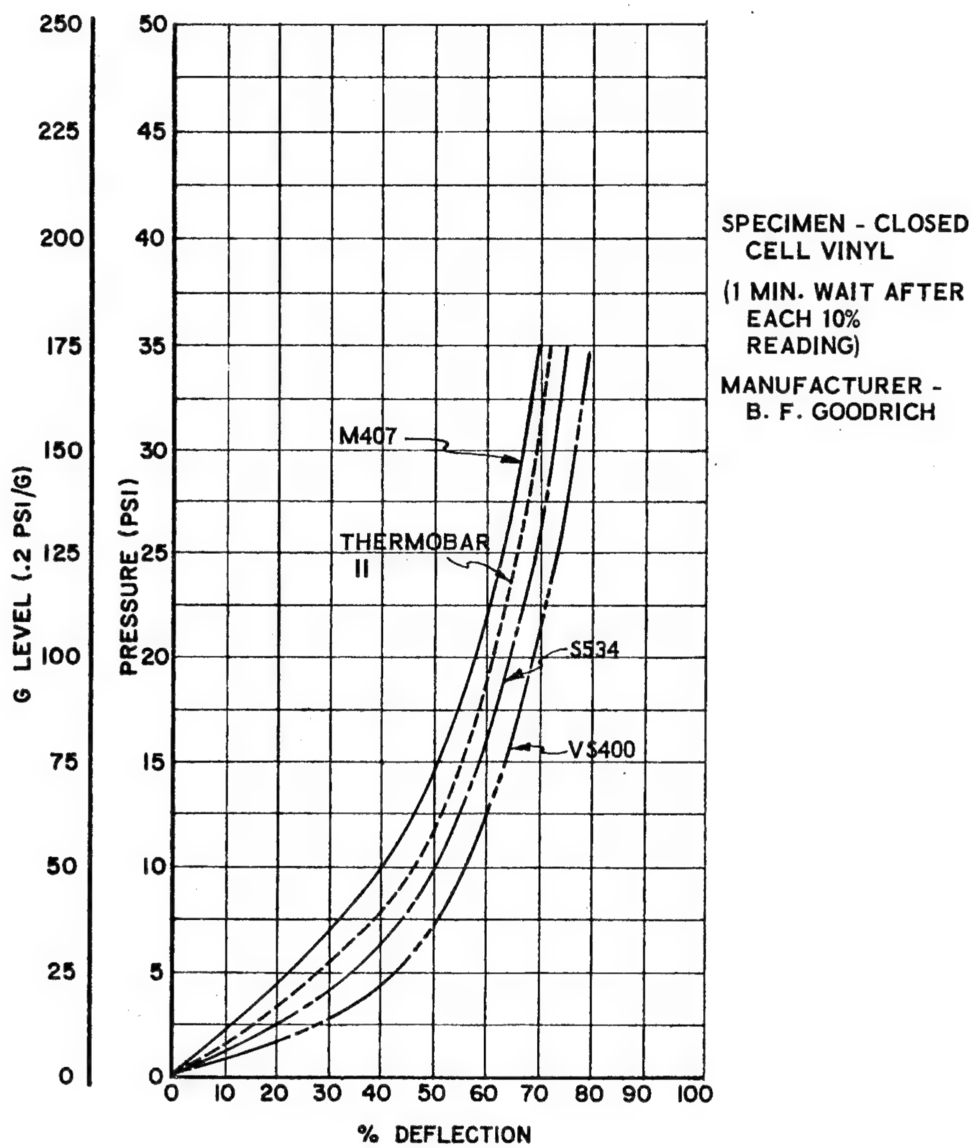
Foam Static Deflection Curve

Figure 37



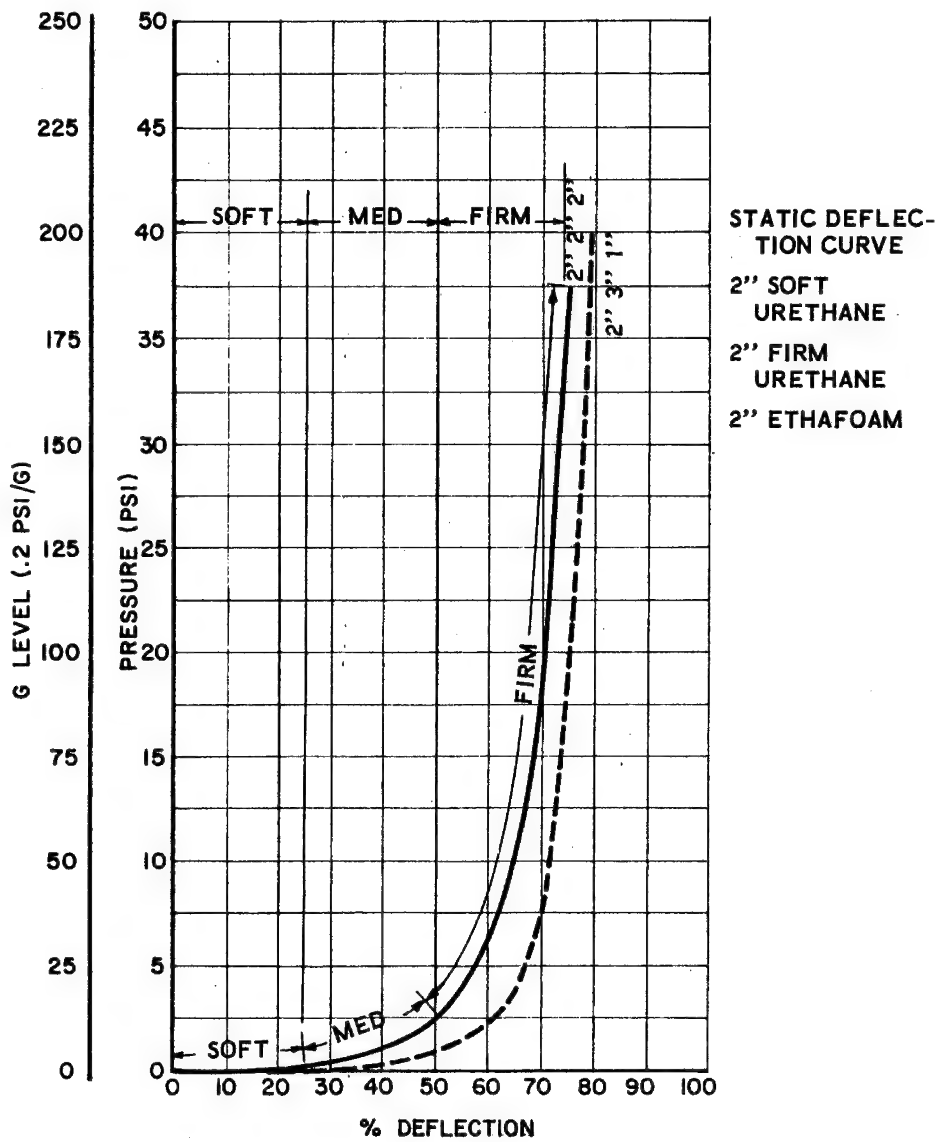
Foam Static Deflection Curve

Figure 38



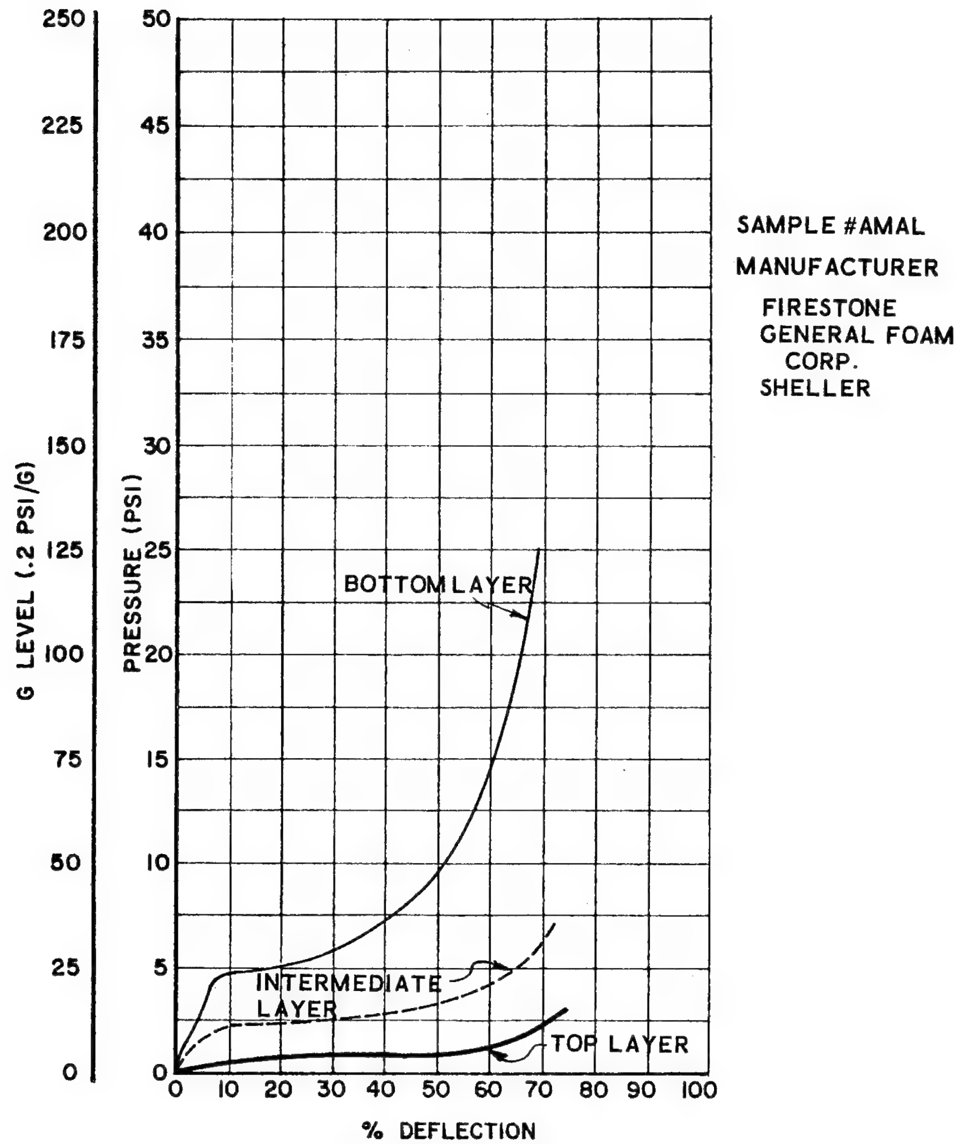
Foam Static Deflection Curve

Figure 39



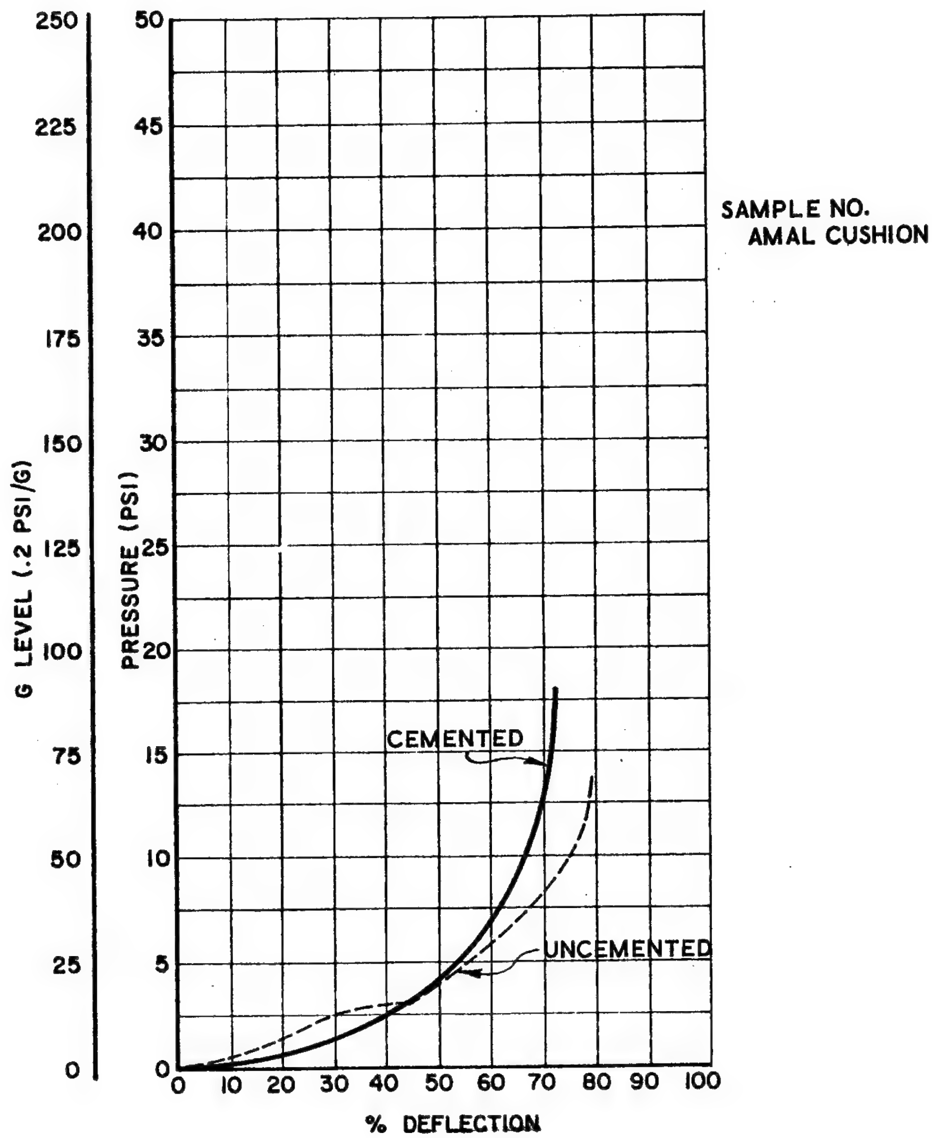
Foam Static Deflection Curve

Figure 40



Foam Static Deflection Curve

Figure 41



Foam Static Deflection Curve

Figure 42

III. VIBRATION AND SHOCK TESTS

This section of the report presents the summary of the vibration and shock tests conducted on the Universal Pilot Couch.

The vibration test commenced on 1 December 1964 and was completed on 3 December 1964. The shock tests were conducted on 4 December 1964. During the vibration test, accelerometers were placed in the head, on the chest, on the lower abdomen and on the table as an input to the couch for the dummy specimen and between the teeth, on the chest, on the lower abdomen and on the table as an input to the couch for each of the human subjects. Figure 43 shows the positions of the accelerometers for the seated and supine human subjects.

All vibration and shock testing was conducted in accordance with the following requirements:

A. Vibration Test Requirements

1. Summary

In these tests we instrumented the test subjects with three accelerometers to evaluate the body and cushion response over the range 0 to 60 cps.

Human tests were conducted at 0.5 G and 1.0 G and for comparison full-size anthropometric dummy tests were conducted over the same range at 1 G and 4 G levels. At the lower frequencies, a 1" maximum double amplitude was used. The total duration for the sweep from 0 to 60 cps and return, was three minutes.

The couch was tested in both the seated and supine test positions as shown in Figure 44. All supine position tests, dummy and manned, were completed prior to remounting the couch for the seated position tests.

2. Vibration Test Procedure

a. Supine Test Position

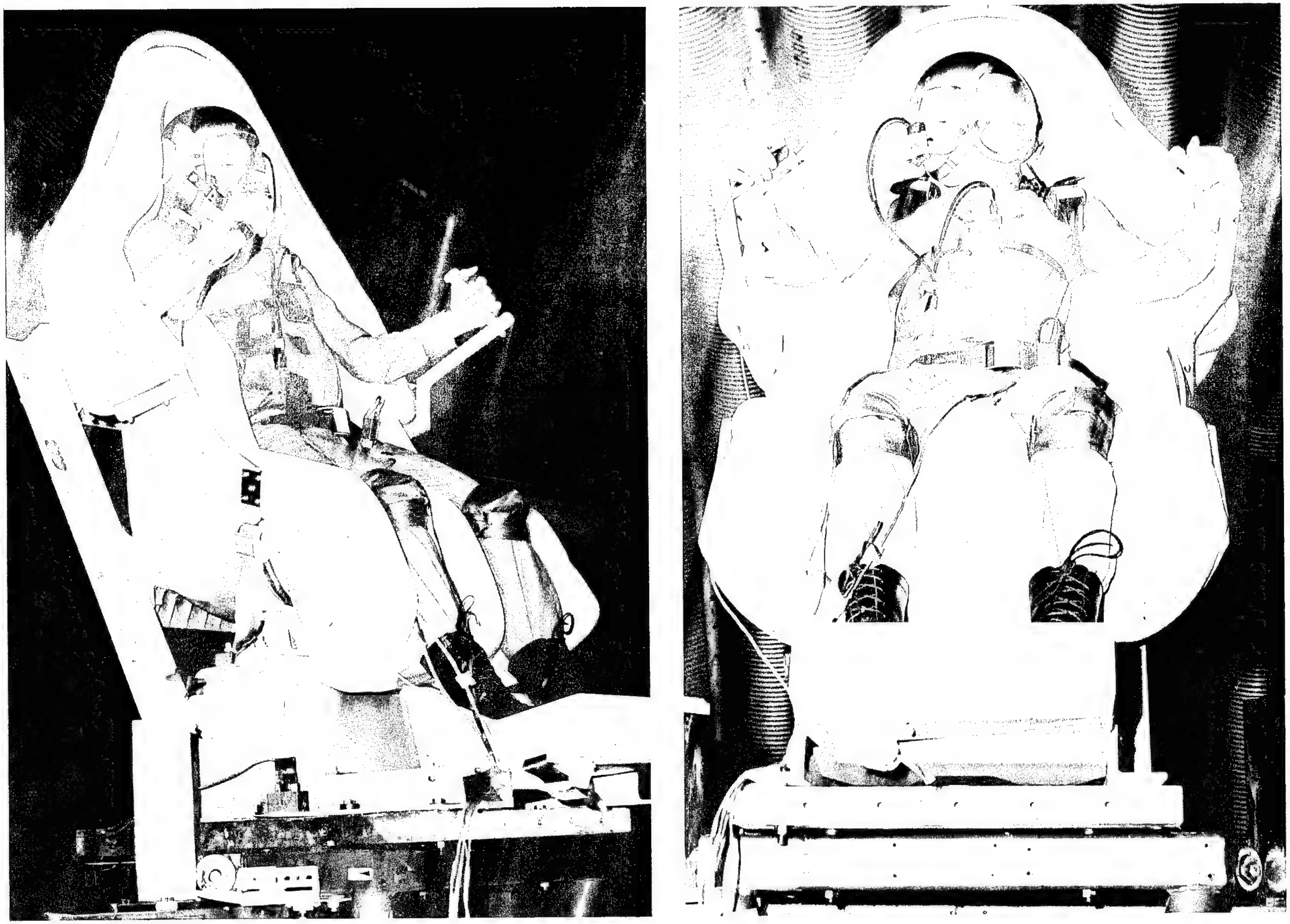
Mount couch as shown in Figure 45

(1) Anthropometric Dummy Tests

(a) Sweep from 0 to 60 cps at 1 G*

(b) Sweep from 0 to 60 cps at 4 G*

* Total duration, 3 minutes. The maximum double amplitude in the lower frequency range was 1".



SET-UP DURING SEATED VIBRATION TESTS

FIGURE 43

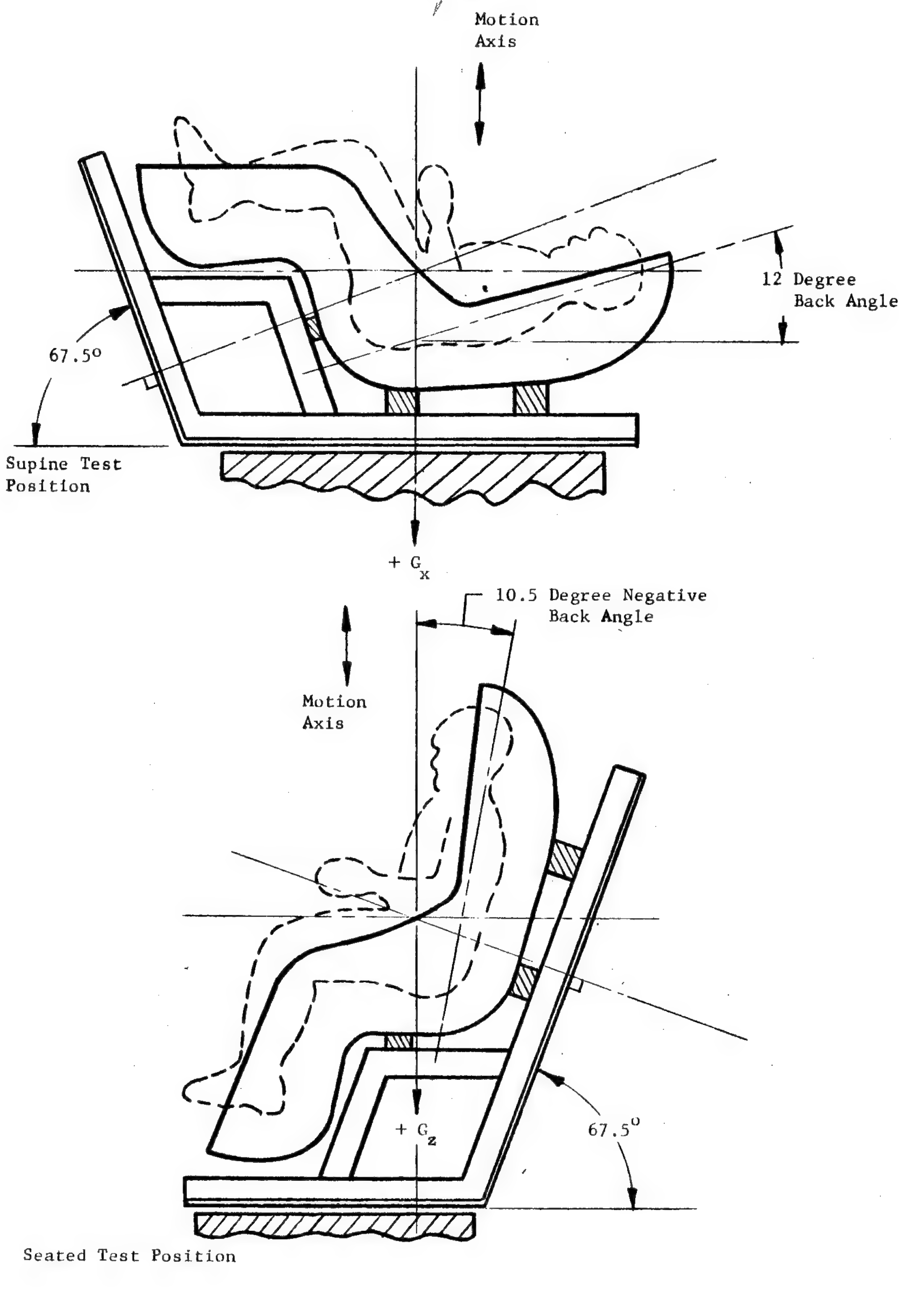
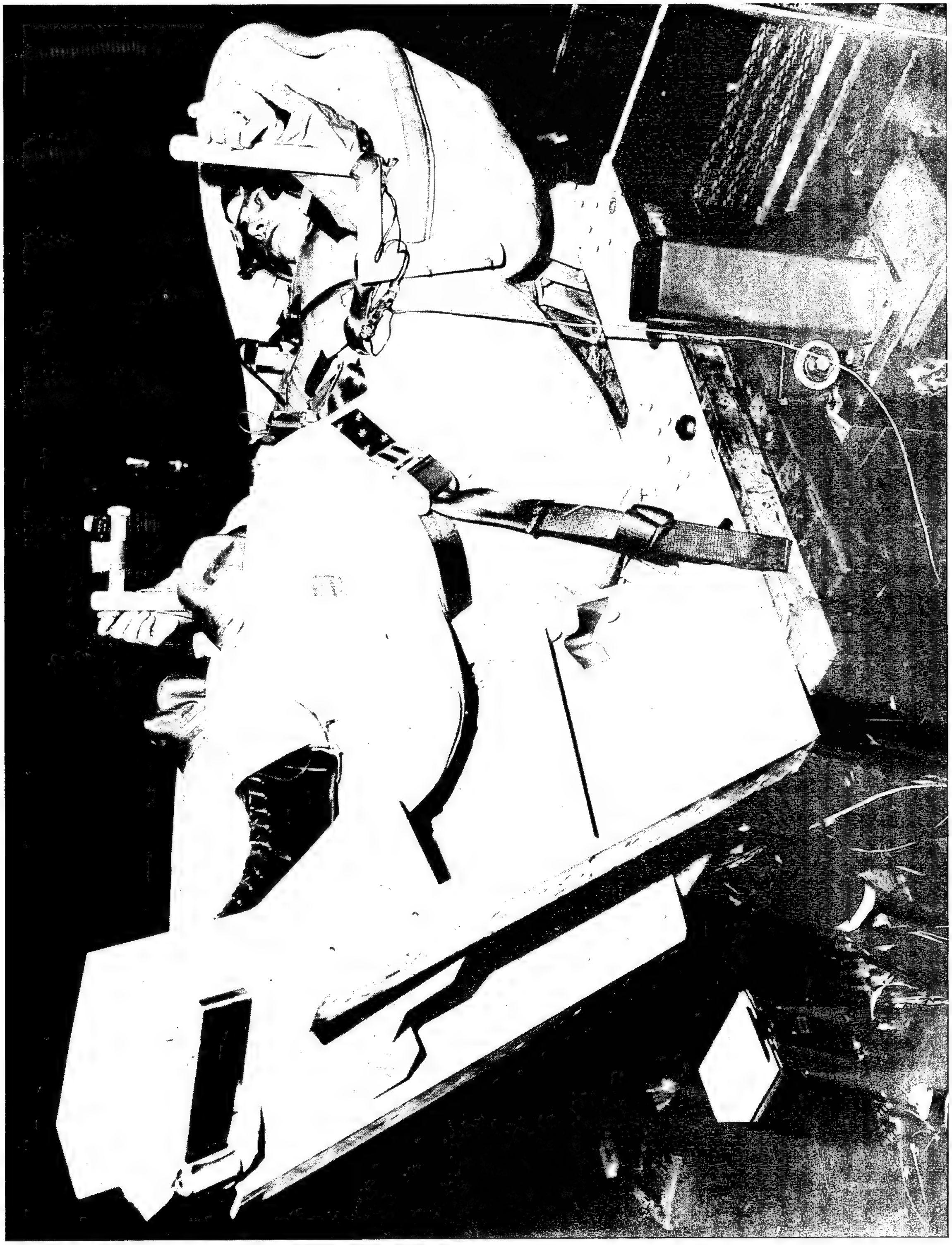

Motion
Axis
12 Degree
Back Angle
67.5°
Supine Test
Position
+ G_x
10.5 Degree Negative
Back Angle
Motion
Axis
+ G_z
67.5°
Seated Test Position

FIGURE 44



TEST SET UP USED DURING SUPINE VIBRATION TESTING

FIGURE 45

(2) Manned Tests - Tests were conducted once for each of two subjects.

(a) Sweep from 0 to 60 cps at 0.5 G*.

(b) Sweep from 0 to 60 cps at 1.0 G*.

b. Seated Test Position

Mount couch as shown in Figure 43.

(1) Anthropometric Dummy Tests

(a) Sweep from 0 to 60 cps at 1 G*.

(b) Sweep from 0 to 60 cps at 4 G*.

(2) Same as a.2.

* Total duration, 3 minutes. The maximum double amplitude in the lower frequency range was 1".

TABLE II

SUMMARY OF VIBRATION TESTS

	DUMMY		SUBJECT 1		SUBJECT 2	
	Supine	Seated	Supine	Seated	Supine	Seated
Sweep 0-60 cps at .5G			X	X	X	X
1G	X	X	X	X	X	X
4G	X	X				

B. Shock Test Requirements

1. Summary

In these tests, we instrumented the test subject with three accelerometers to determine acceleration-time characteristics when the couch was subjected to isometric shock pulses of 10 G 20 MS duration and 20 G 40 MS duration. For comparison, full size anthropometric dummy tests were conducted with shock pulses of 10 G 20 MS duration, 20 G 40 MS duration and 40 G 40 MS duration.

The couch was tested in both the seated and supine test positions as shown in Figures 43 and 45. All supine position tests, dummy and manned, were completed prior to remounting the couch for the seated positions tests.

2. Shock Test Procedure

a. Supine Test Position

Mount Couch as shown in Figure 45.

(1) Anthropometric Dummy Tests

(a) 10 G maximum acceleration input to the base of the couch, 20 MS maximum pulse duration.

(b) 20 G maximum acceleration 40 MS maximum duration.

(c) 40 G maximum acceleration 40 MS maximum duration.

(2) Manned Tests

Tests were conducted once for each of two subjects.

(a) 10 G maximum acceleration 20 MS maximum duration.

(b) 20 G maximum acceleration 40 MS maximum duration.

b. Seated Test Position

Mount Couch as shown in Figure 43.

(1) Anthropometric Dummy Tests

(a) 10 G maximum acceleration input to the base of the couch, 20 MS maximum pulse duration.

(b) 20 G maximum acceleration 40 MS maximum duration.

(c) 40 G maximum acceleration 40 MS maximum duration.

(2) Manned Tests

Tests were conducted once for each of two subjects.

(a) 10 G maximum acceleration 20 MS maximum duration.

TABLE III

SUMMARY OF SHOCK TESTS

TEST	DUMMY		SUBJECT 1		SUBJECT 2	
	Supine	Seated	Supine	Seated	Supine	Seated
10 G 20 MS	X	X	X	X	X	X
20 G 40 MS	X	X	X		X	
40 G 40 MS	X	X				

The list of the test equipment shown in Table IV was utilized during the vibration and shock tests. The Test Equipment was calibrated in the Dayton T. Brown, Inc. Standards Laboratory with all calibrations directly traceable to the National Bureau of Standards.

TABLE IV

TEST EQUIPMENT

ITEM	MANUFACTURER	MODEL	S/N	CAL. PERIOD	DATE OF LAST CAL.	ACCURACY	Used in Para. No.
Servo Valve	Pegasus Laboratories, Inc.	1160G	121		Each Use		
Low Frequency Oscillator	Hewlett Packard Co.	202C	1897	3 Months	20 NOV 64	± 2%	
Velocity Pick-Up	M.B. Electronics	126	13674	6 Months	7 OCT 64	± 5%	
Velocity Pick-Up	C. E. C.	4-1020	24320	Before Each Use		± 5%	
Vibration Meter	M. B. Electronics	M6	41-1	1 Month	14 NOV 64	± 2%	
Accelerometers	Statham Labs..	A5A-350	6822 4732	6 Months	5 OCT 64	± 2%	
Accelerometers	Statham Labs.	A5A-350	6822 3252	6 Months	5 Oct 64 13 OCT 64	± 2%	
Hydraulic Power Supply	M.B. Electronics			Each Use			
Transducer	Statham Labs.	A5A-350	10587 3960	6 Months	2 OCT 64 5 OCT 64	± 2%	
Power Supply	C. E. C.	2-105A	13023	6 Months	6 NOV 64	-	
Amplifier	C. E. C.	1-113B	22039	6 Months	5 OCT 64	-	
Recorder	Midwestern Instruments	621-HT	23-5	6 Months	24 SEP 64	± 2%	
Tuning Fork	General Radio Co.	723D	2131	6 Months	5 AUG 64	± 1%	
Shock Machine	Dayton T. Brown, Inc.	2000		Each Test			

C. Detailed Test Procedure

Prior to the arrival of the test items, the Consolidated Electronics Corp. high displacement pick-up was calibrated against an M. B. Electronics velocity type pick-up and a V-Scope. Prior to the vibration test, the Statham accelerometers supplied by Dayton T. Brown, and the recorder supplied by Aircraft Armaments, Inc. were calibrated by placing the four accelerometers in the same axis on the hydraulic vibrator and recording the output of all of accelerometers. The records were checked for uniformity of wave shape and magnitude.

All records taken during the tests on the dummy and live specimens were retained by the Aircraft Armaments personnel present. The following inputs were monitored on the couch. Figure 43 illustrates the mounting method of the hydraulic vibrator and Figure 44 designates the axes used during the vibration test.

Dummy - Supine

Frequency Bandwidth (cps)	Applied Force
1 - 11	4 in. D.A. or ± 1.0 g
10 - 60	± 1.0 g
1 - 2	4 in. D. A.
2 - 11	1 in. D.A. or ± 4.0 g
10 - 60	± 4.0 g

Dummy - Seated

Frequency Bandwidth (cps)	Applied Force
1 - 2	4 in. D.A.
2 - 11	1 in. D.A. or ± 1.0 g
10 - 60	± 1.0 g
1 - 2	4 in. D.A.
2 - 11	1 in. D.A. or ± 4.0 g
10 - 60	± 4.0 g

Subject 1 - Seated

Frequency Bandwidth (cps)	Applied Force	Duration*
1 - 60	1 in. D.A. or ± .5 g	3.7 min.
1 - 25	1 in. D.A. or ± 1.0 g	3.0 min.
10 - 60	± 1.0 g	2.6 min.
1 - 10	1 in. D.A, or ± 1.0 g	2.8 min.

* Additional time on vibrator due to recorder difficulty.

Subject 2 - Seated

Frequency Bandwidth (cps)	Applied Force	Duration
1 - 60	1 in. D.A. or ± .5 g	*
1 - 60	1 in. D.A. or ± 1.0 g	*

* Not Recorded

Subject 2 - Supine

Frequency Bandwidth (cps)	Applied Force	Duration
1 - 60	1 in. D.A. or ± .5 g	4 min.
1 - 30	1 in. D.A. or ± 1.0 g	1.8 min.

Subject 1 - Supine

Frequency Bandwidth (cps)	Applied Force	Duration
1 - 30	1 in. D.A. or ± .5 g	1.8 min.
1 - 30	1 in. D.A. or ± 1.0 g	2.8 min.

The vibration tests were completed on 3 DEC 1964.

D. Vibration Test Summary

In all, 16 tests were made including human and dummy subjects in both seated and supine positions against the following schedule:

TABLE V

VIBRATION TEST PARAMETERS

Acceleration	.5 G		1.0 G		4.0 G	
Position	Seated	Supine	Seated	Supine	Seated	Supine
Dummy			X	X	X	X
Human	X	X	X	X		

Figures 46 - 49 are representative traces of the raw data. Figure 46 shows the trace at the natural frequency of 4 cps for the dummy run at 4 G vector, seated. The amplification ratio (output over input) at the natural frequency is approximately 2.0.

Figure 47 shows the traces for a human run seated approximately 1 cycle above the natural frequency where the amplification factor is again approximately 2.0. Figures 48 and 49, drawn from the raw data as examples, show the dummy and human supine tests results.

Figures 50 through 62 are plots of the ratio of output over input by frequency for 13 of the 15 tests conducted. Data for three of the dummy runs was unusable. Most figures show a natural frequency of approximately 4 - 5 cps., but the amplification factors are quite different, slightly over two for the dummy and 3 - 4 for the human subject. All plots cross over unity amplification at approximately 6 cps.

Table VI presents a summary of all vibration runs. From this summary the following basic conclusions can be stated:

1. The average peak transmissibility ratio of all accelerometers mounted at the head, dummy and human seated and supine equals 2.63.

2. The average peak transmissibility ratio of all accelerometers at the chest, dummy and human, seated and supine equals 2.46.

3. The average peak transmissibility ratio of all accelerometers at the human's thigh seated equals 1.89.

4. The average peak transmissibility ratio of all accelerometers at human's pelvis supine equals 2.03.

5. The average peak transmissibility ratio seated all accelerometers dummy and human equals 2.47.

6. The average peak transmissibility ratio supine all accelerometers dummy and human equals 2.33.

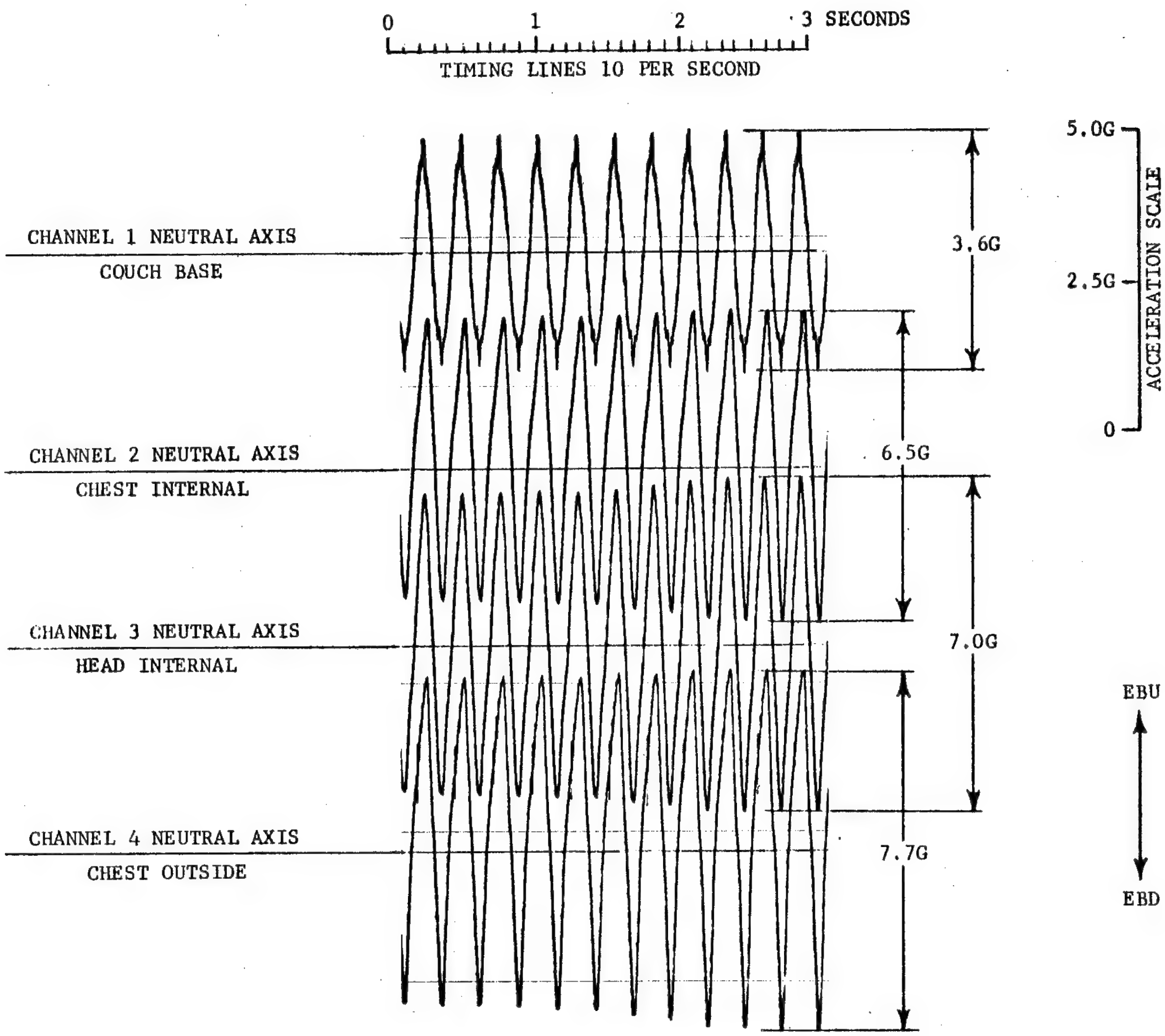
7. The average natural frequency all accelerometers seated equals 4.375 cps.

8. The average natural frequency all accelerometers supine equals 6.47 cps.

9. The average cross over seated equals 7.07 cps.

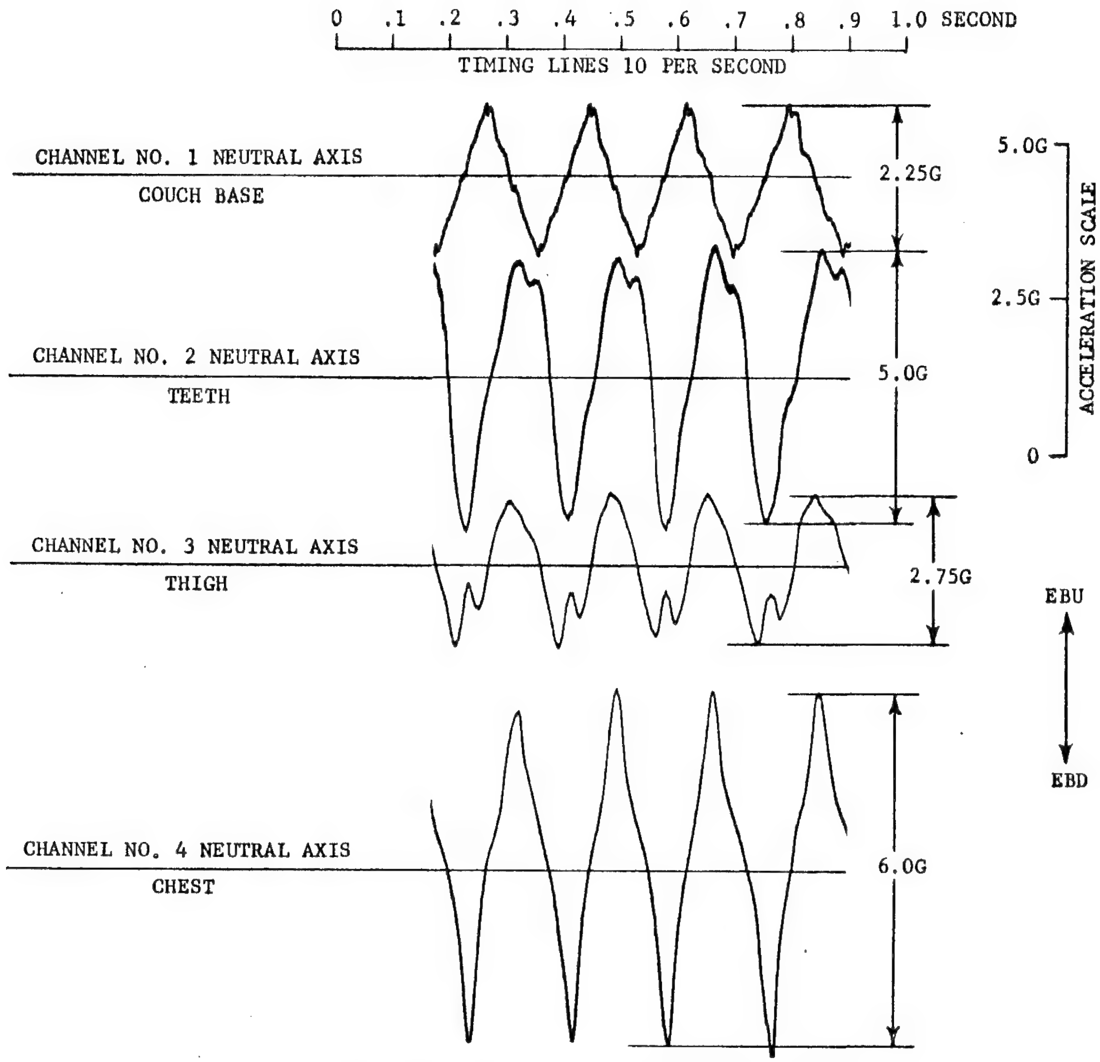
10. The average cross over supine equals 10.2 cps.

11. The average frequency where transmissibility equals .2 equals 20 cps.



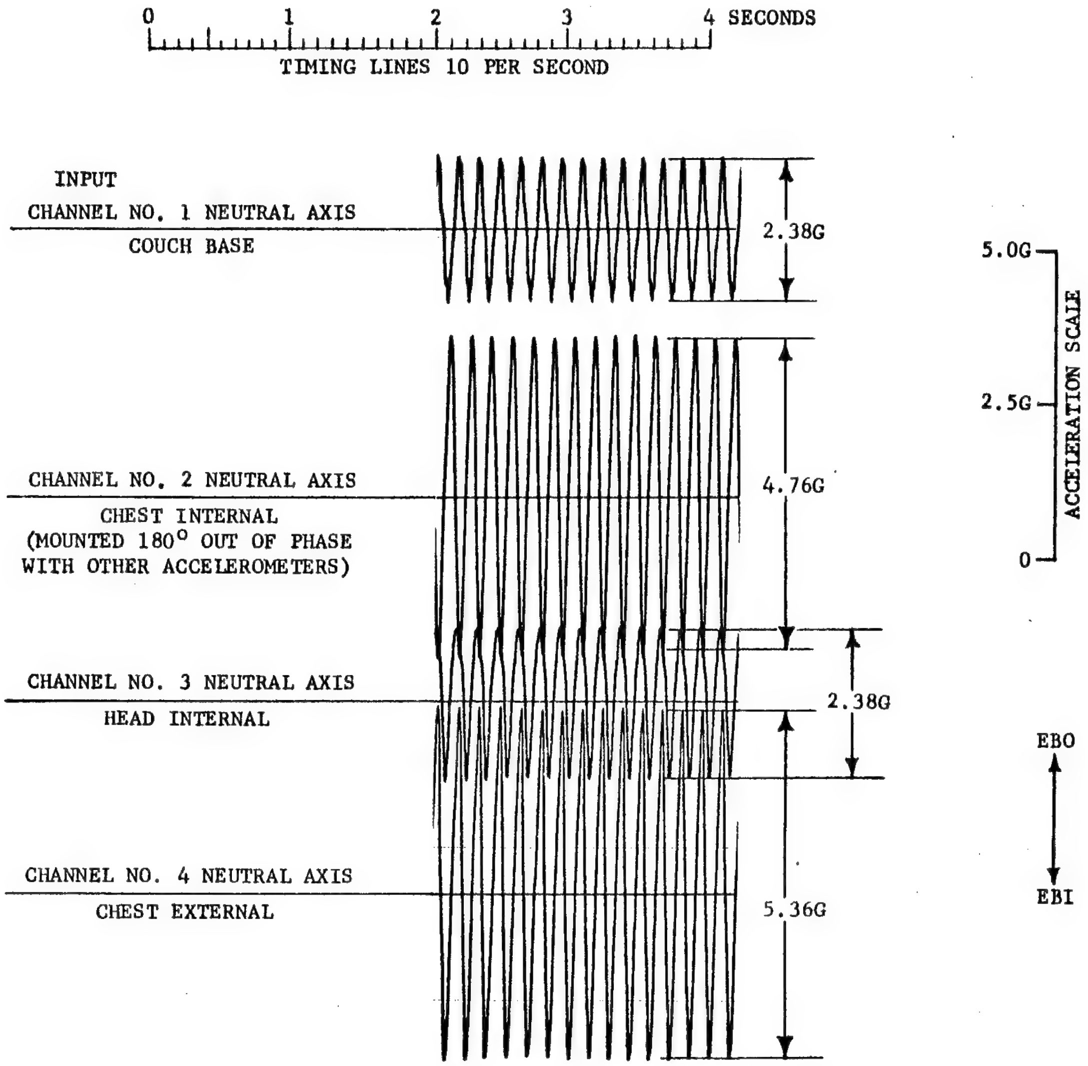
VIBRATION TEST NO. 6, ACCELERATION TRACES
SUBJECT: DUMMY
POSITION: SEATED
FREQUENCY: 4 CPS

Figure 46



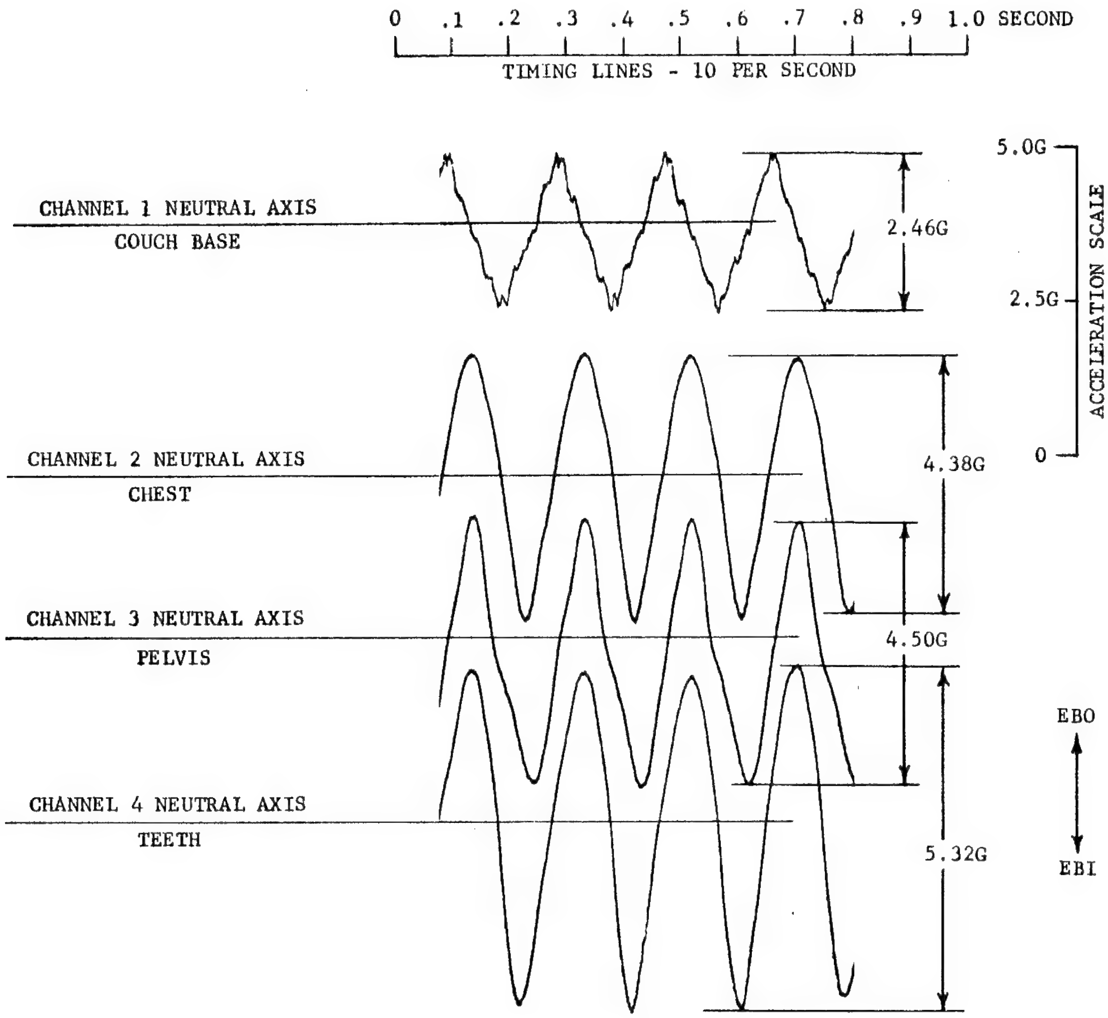
VIBRATION TEST NO. 8, ACCELERATION TRACES
SUBJECT: LMM
POSITION: SEATED
FREQUENCY: 5.5 CPS

Figure 47



VIBRATION TEST NO. 2, ACCELERATION TRACES
SUBJECT: ANTHROPOMETRIC DUMMY
POSITION: SUPINE
FREQUENCY: 7 CPS

Figure 48



VIBRATION TEST NO. 15
SUBJECT: LMM
POSITION: SUPINE
FREQUENCY: 5

Figure 49

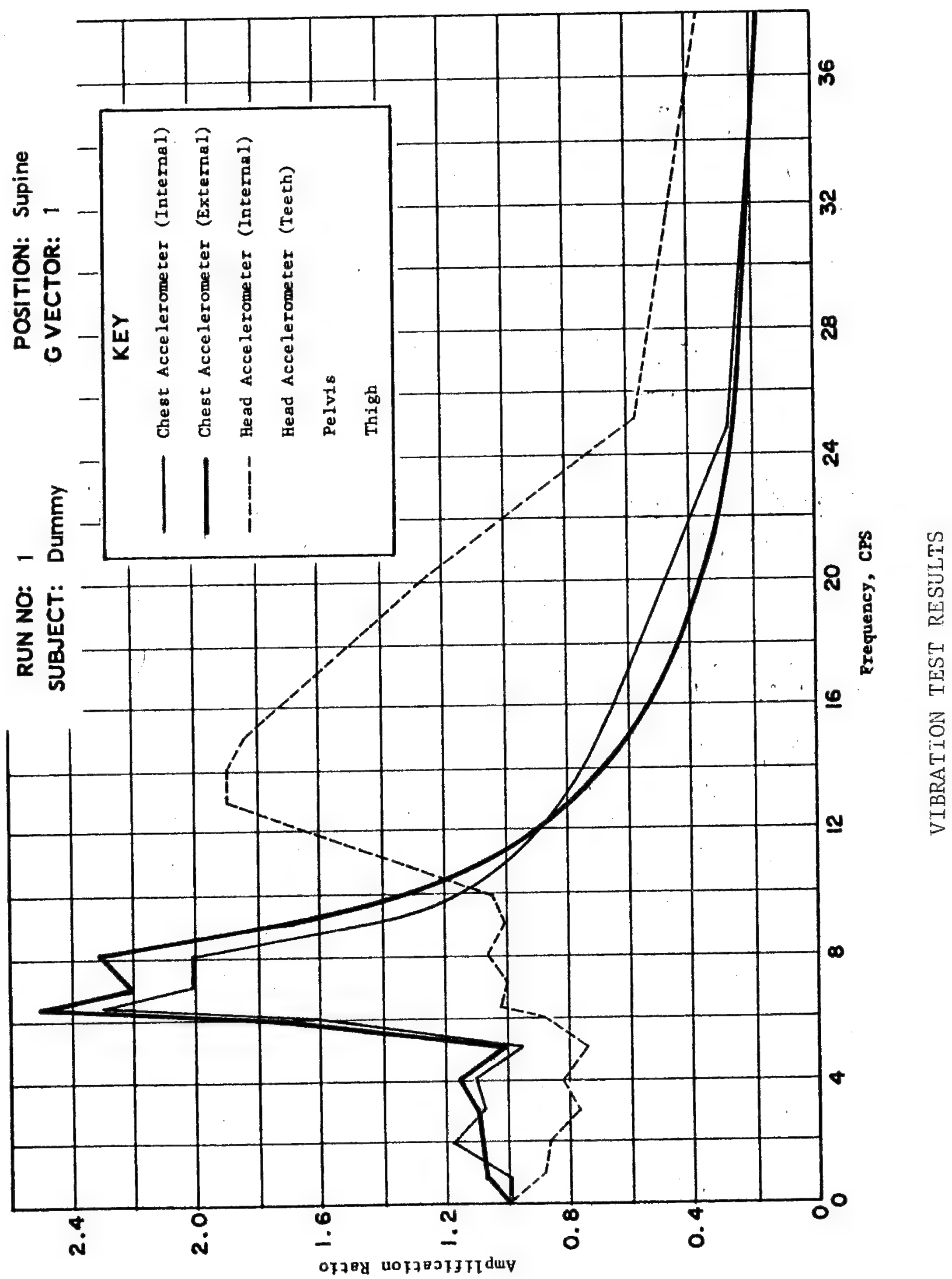
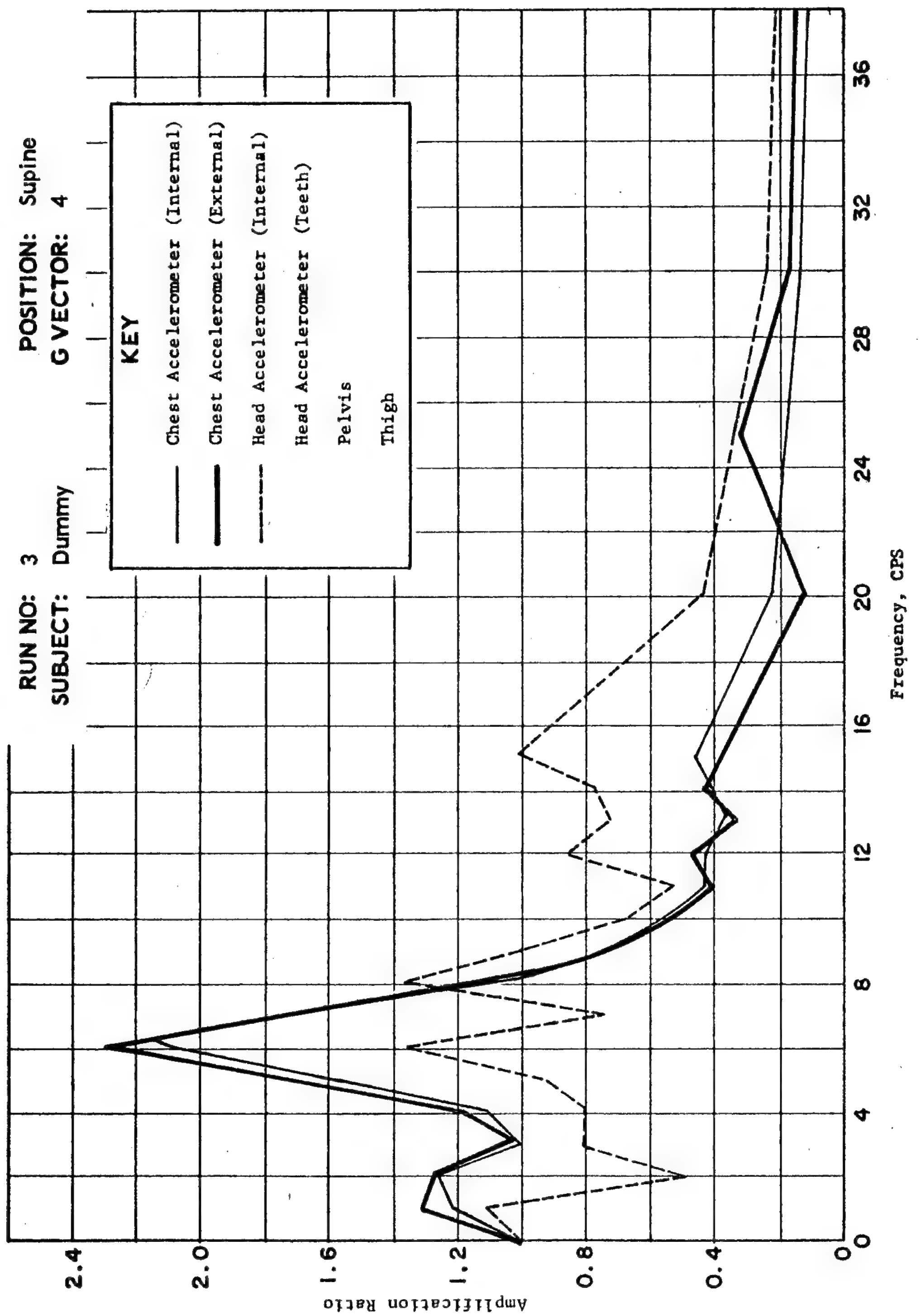
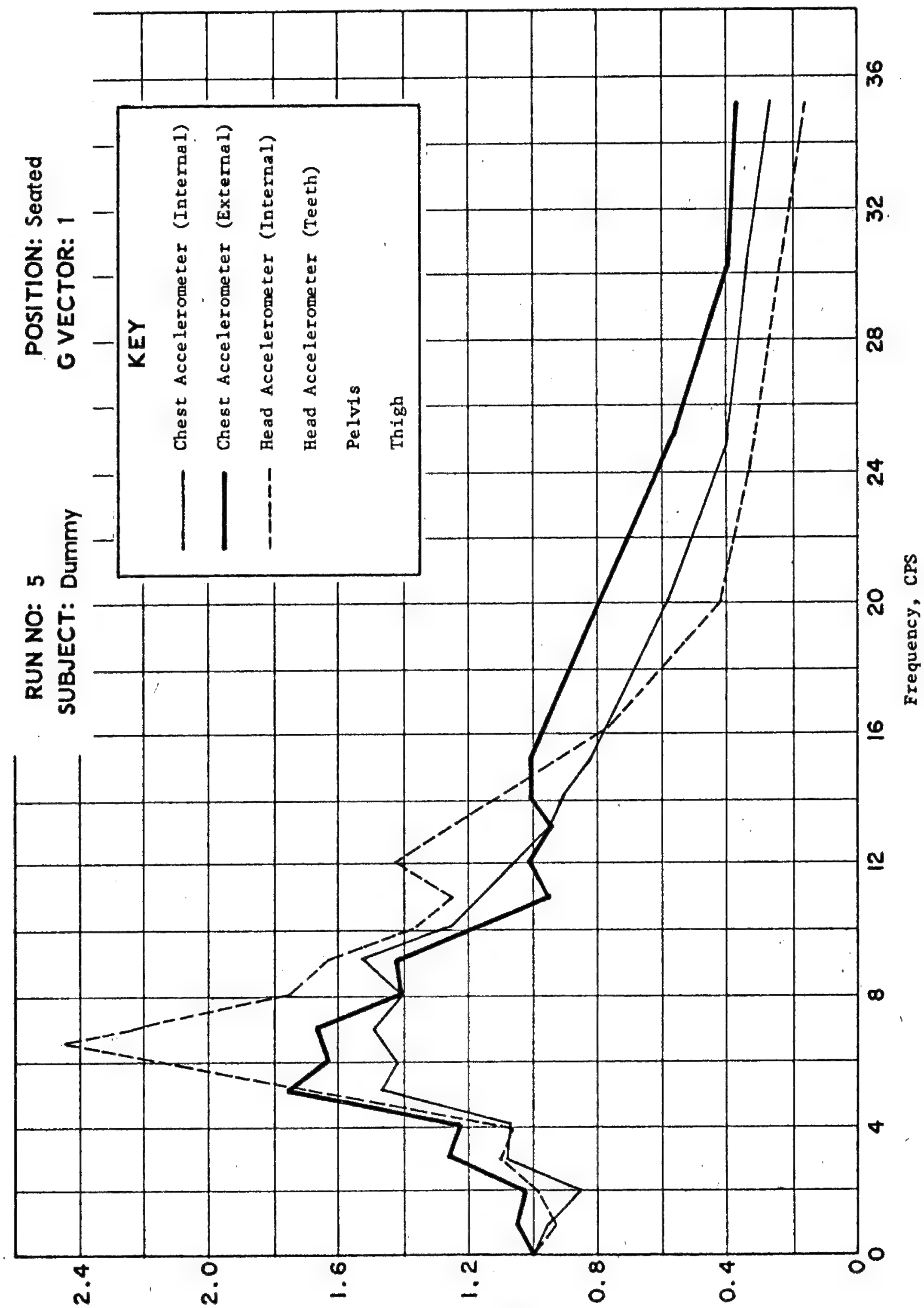

RUN NO: 1
SUBJECT: Dummy
POSITION: Supine
G VECTOR: 1
KEY
Chest Accelerometer (Internal)
Chest Accelerometer (External)
Head Accelerometer (Internal)
Head Accelerometer (Teeth)
Pelvis
Thigh
Amplification Ratio
0
0.4
0.8
1.2
1.6
2.0
2.4
Frequency, CPS
0
4
8
12
16
20
24
28
32
36
VIBRATION TEST RESULTS

Figure 50

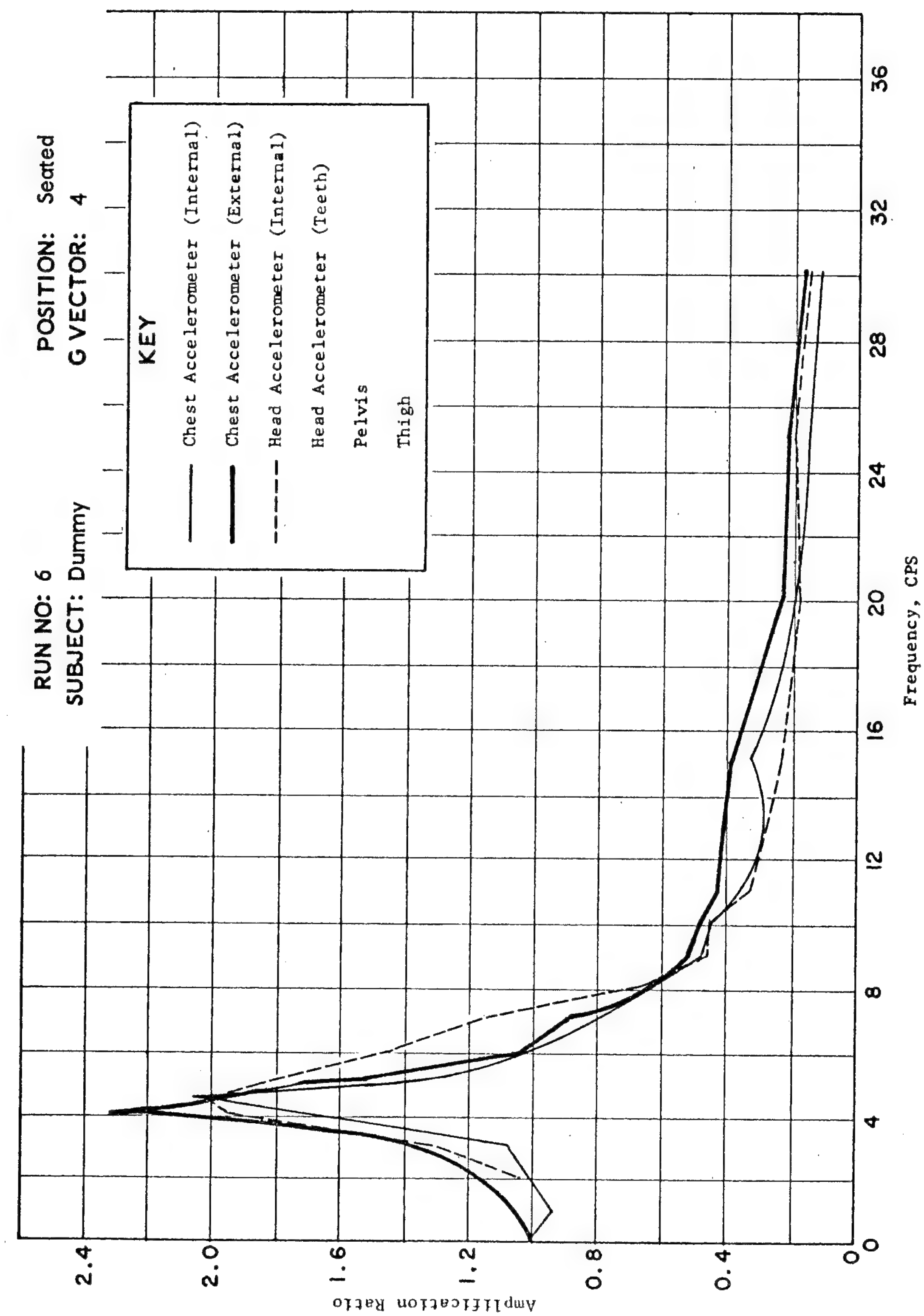


VIBRATION TEST RESULTS

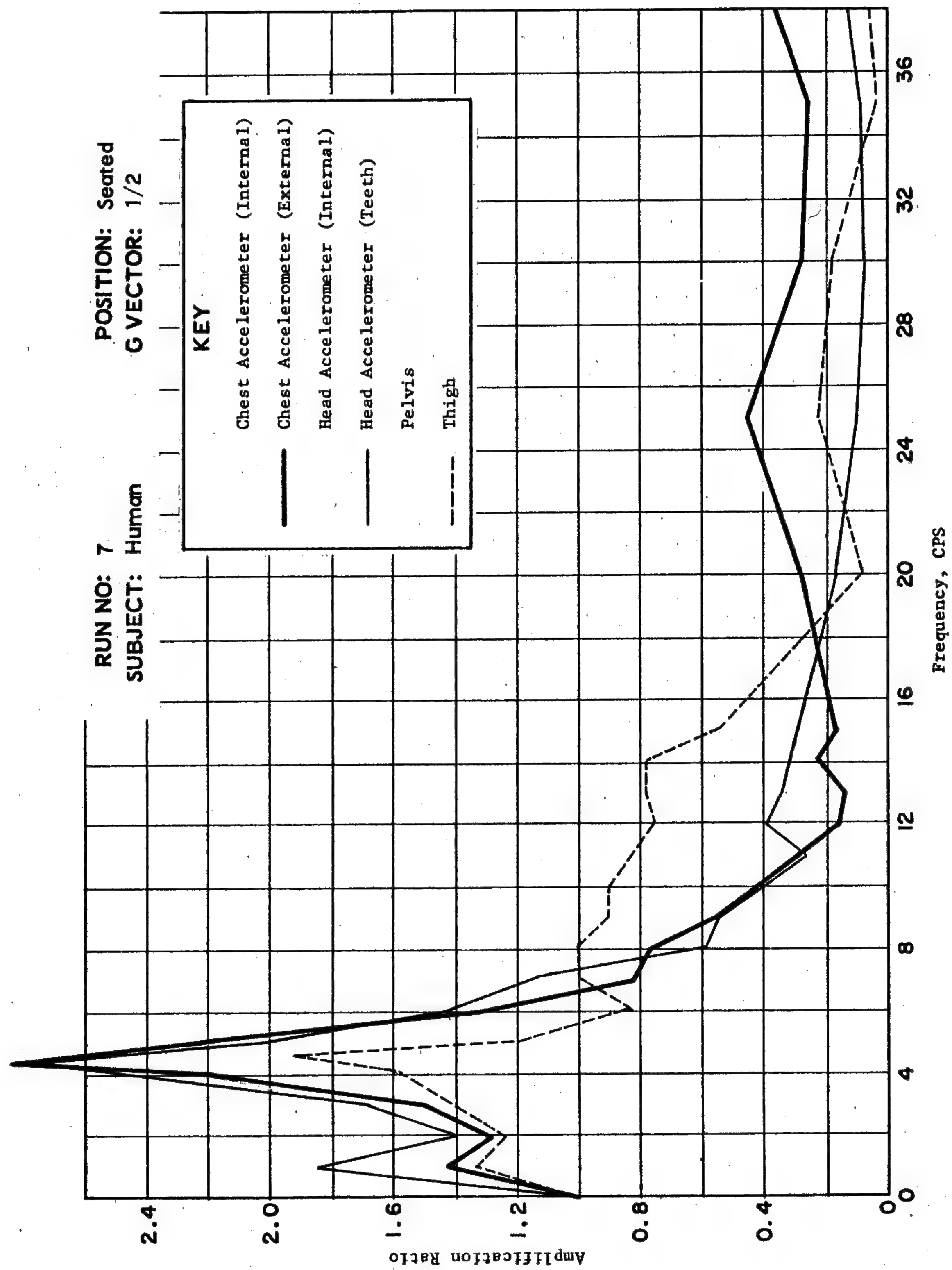
Figure 51



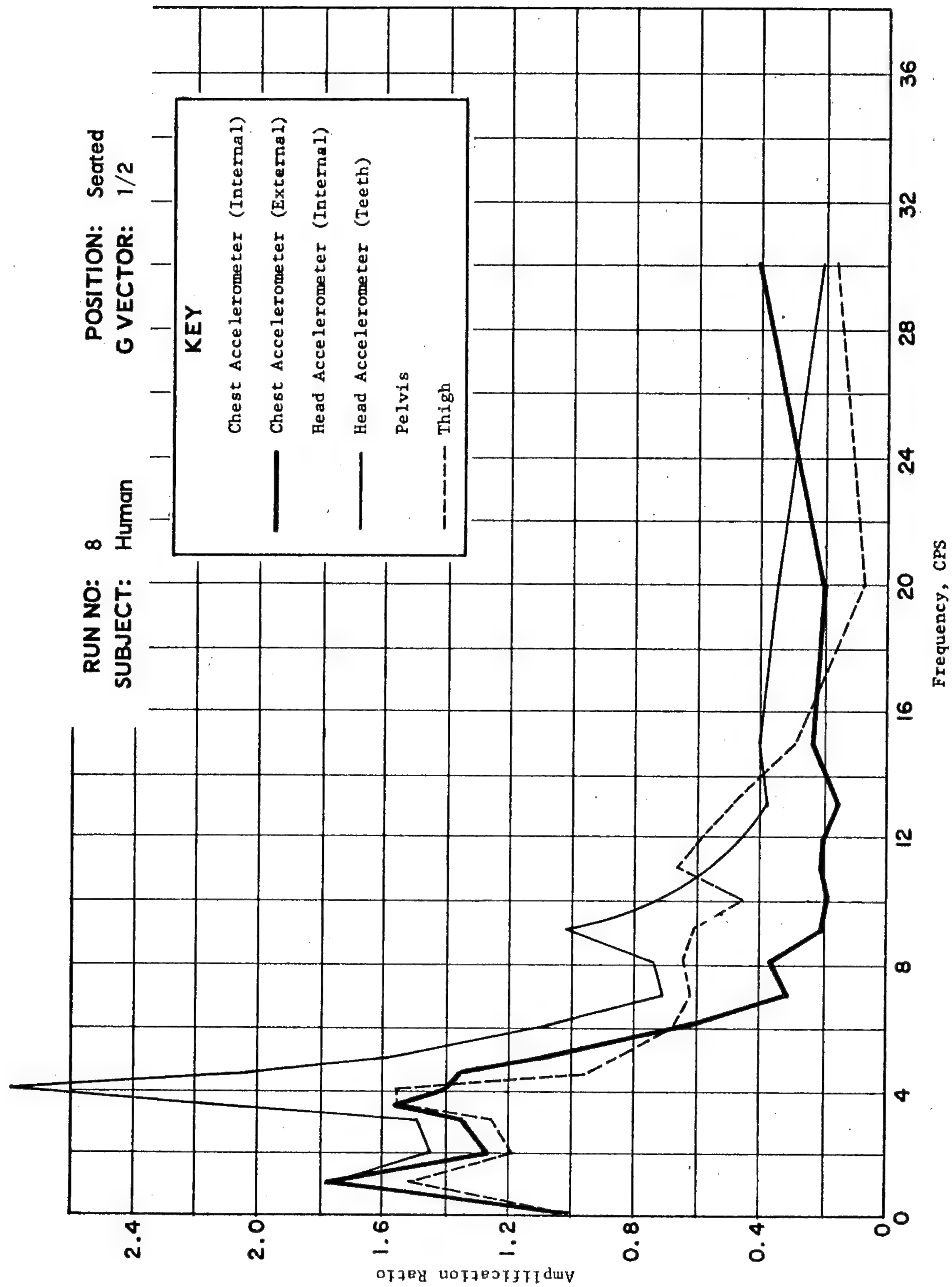
VIBRATION TEST RESULTS
Figure 52



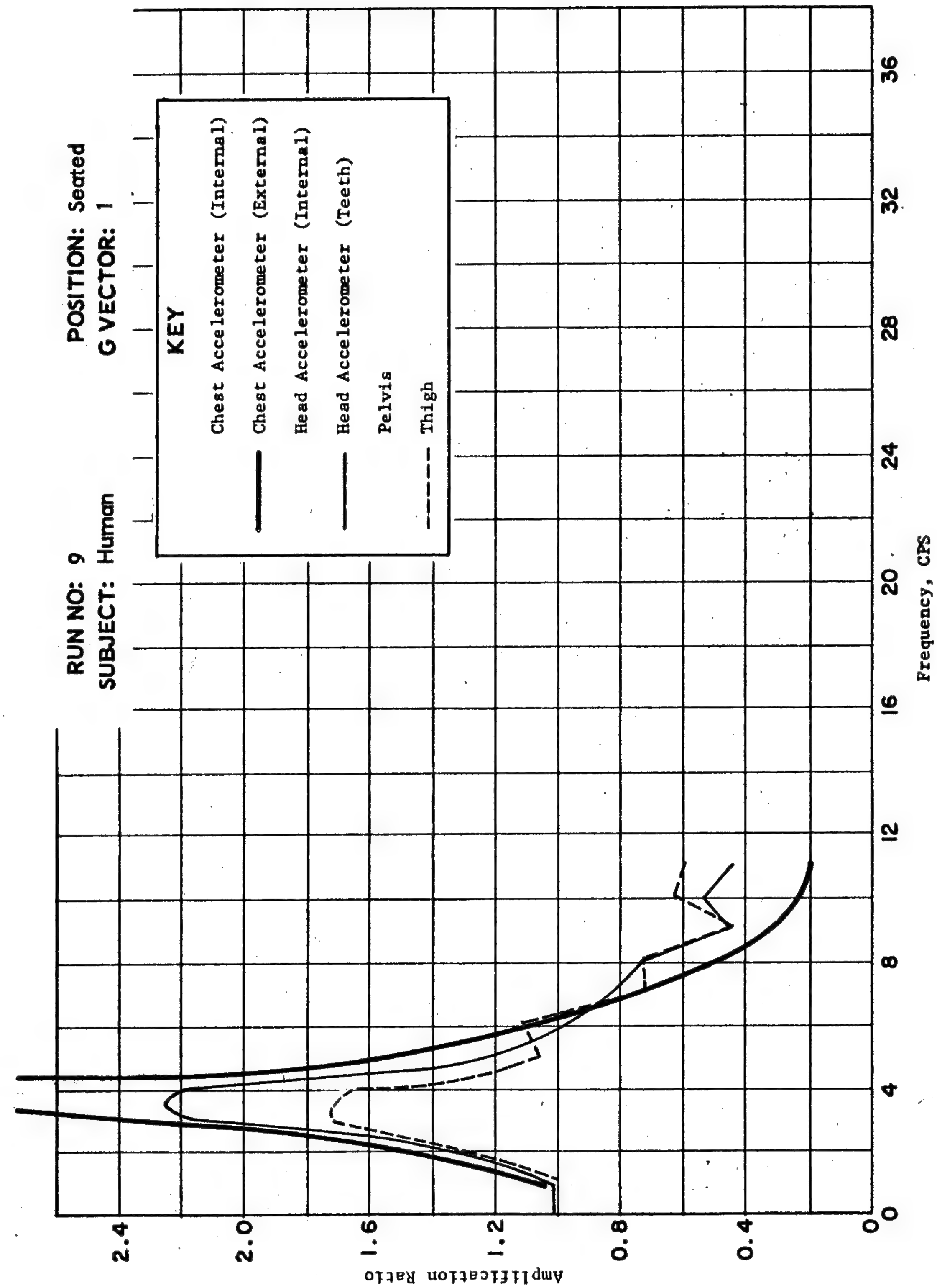
VIBRATION TEST RESULTS
Figure 53



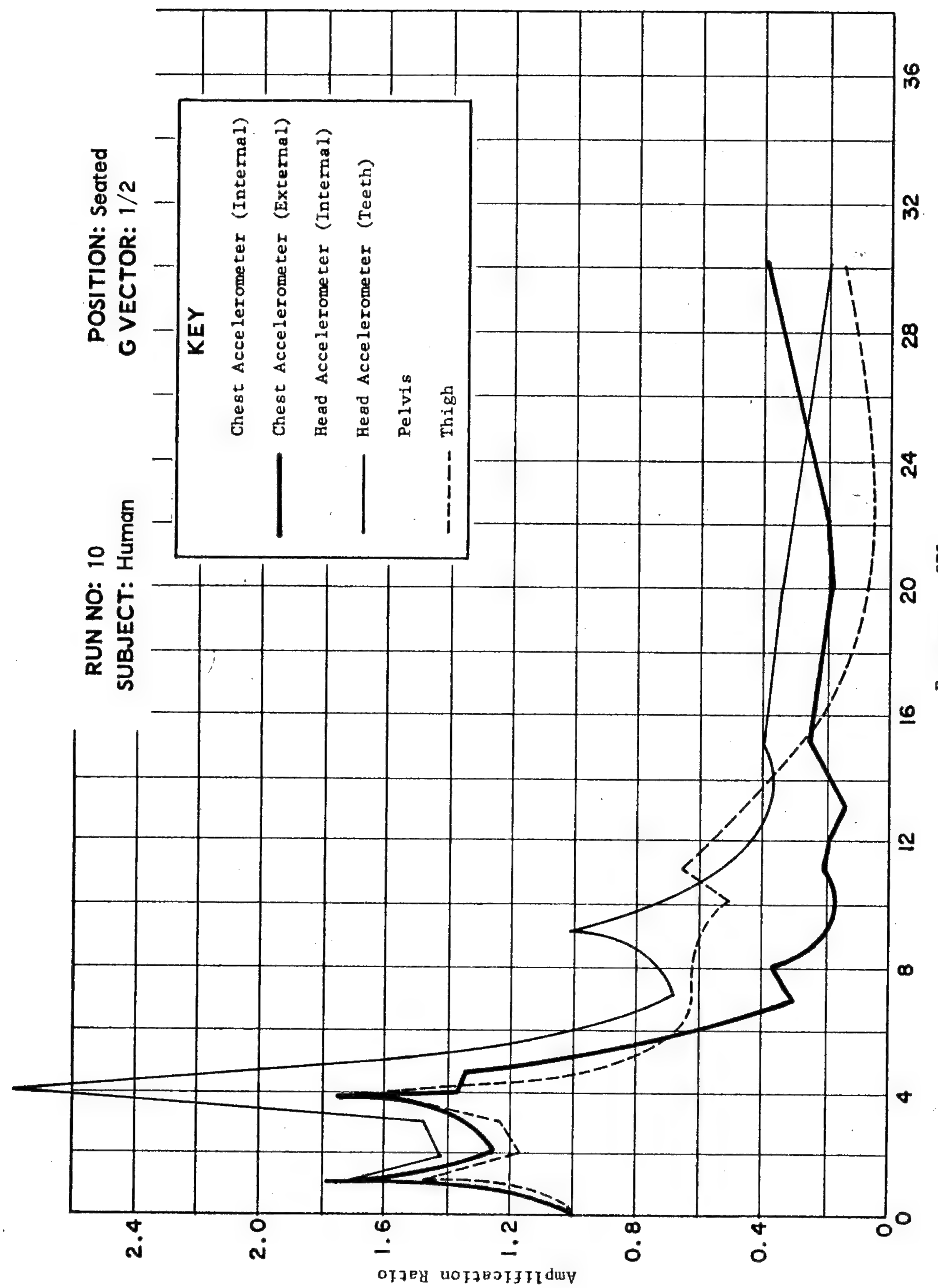
VIBRATION TEST RESULTS
Figure 54



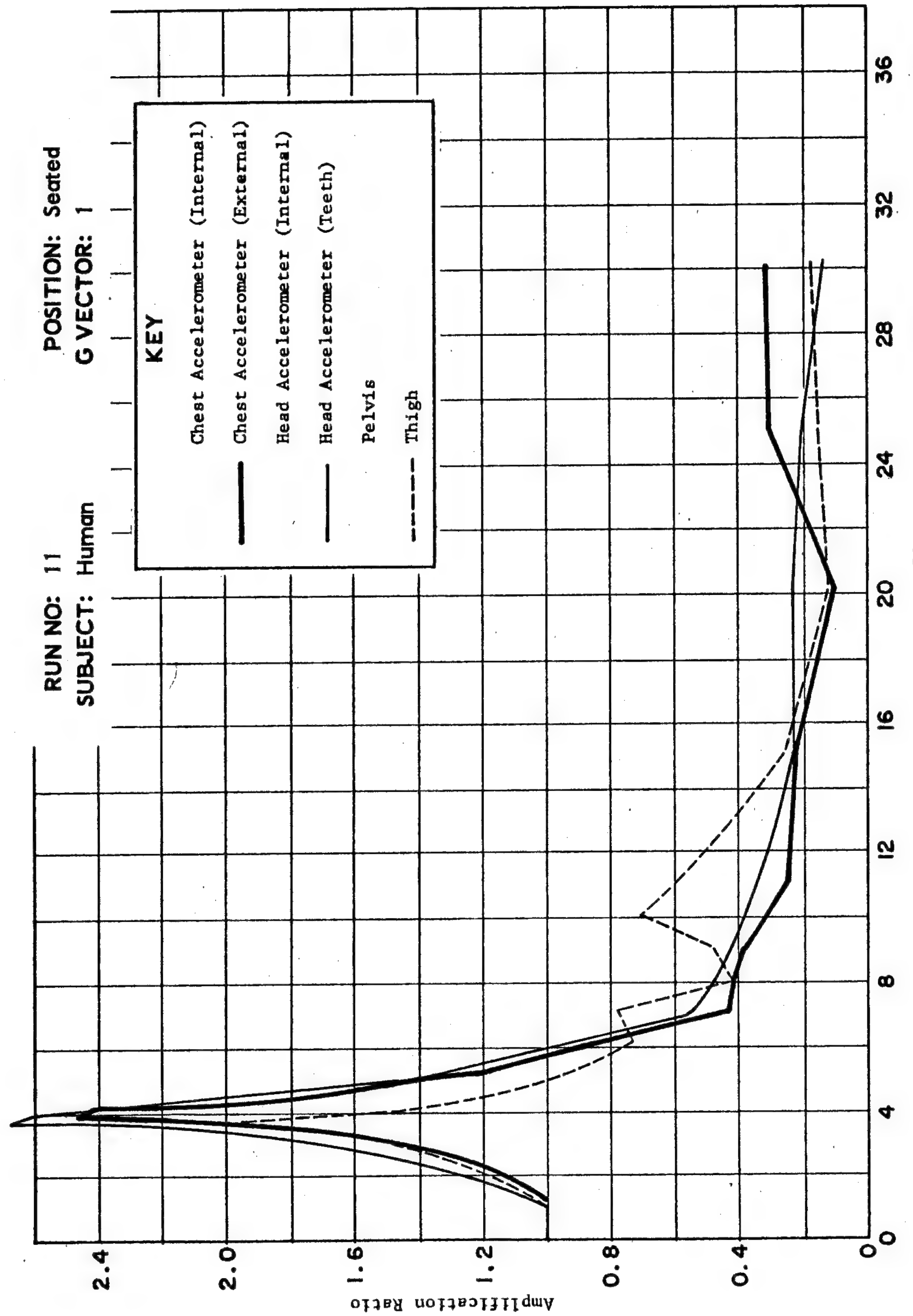
VIBRATION TEST RESULTS
Figure 55



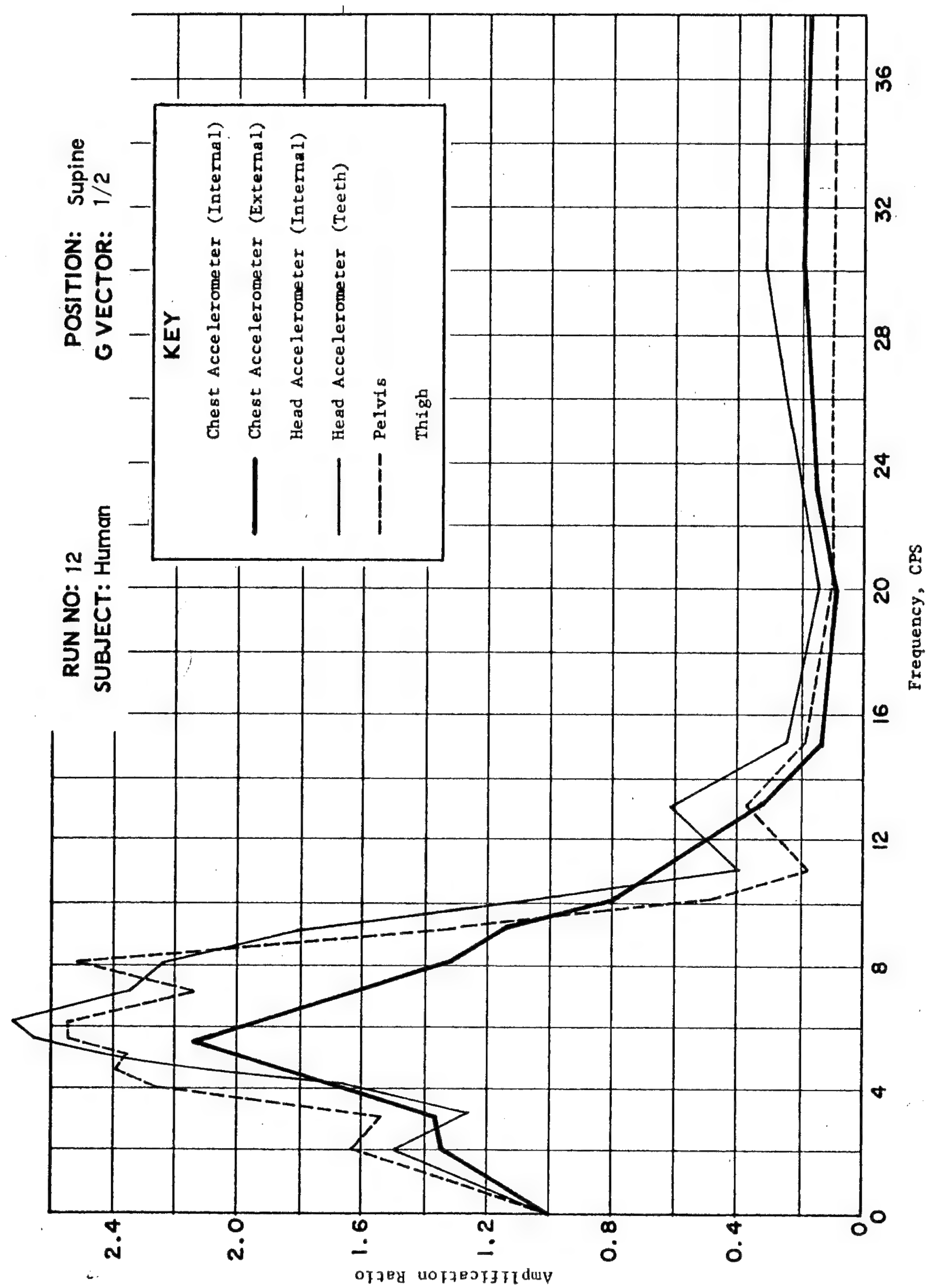
VIBRATION TEST RESULTS
Figure 56



VIBRATION TEST RESULTS
Figure 57

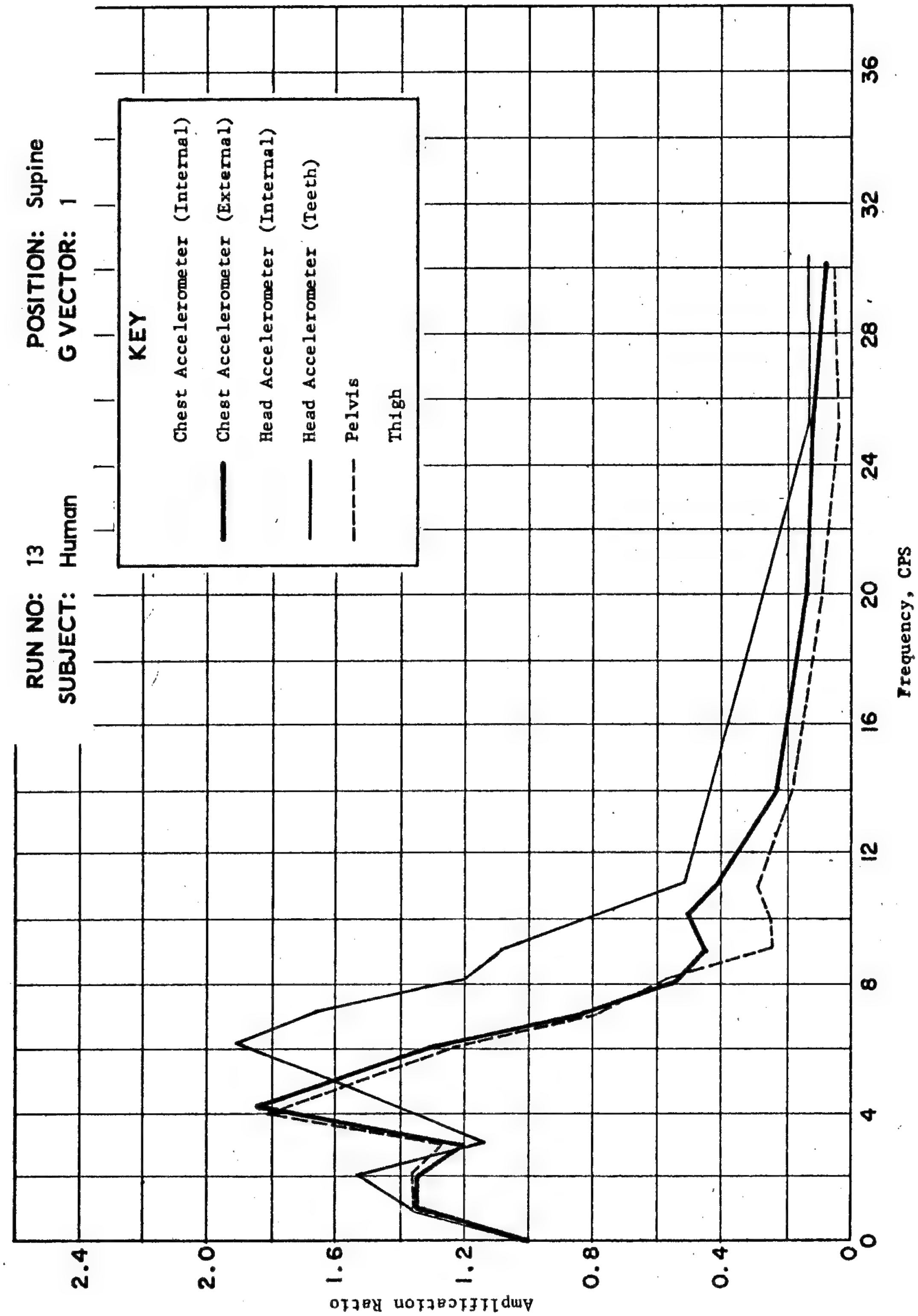


VIBRATION TEST RESULTS
Figure 58

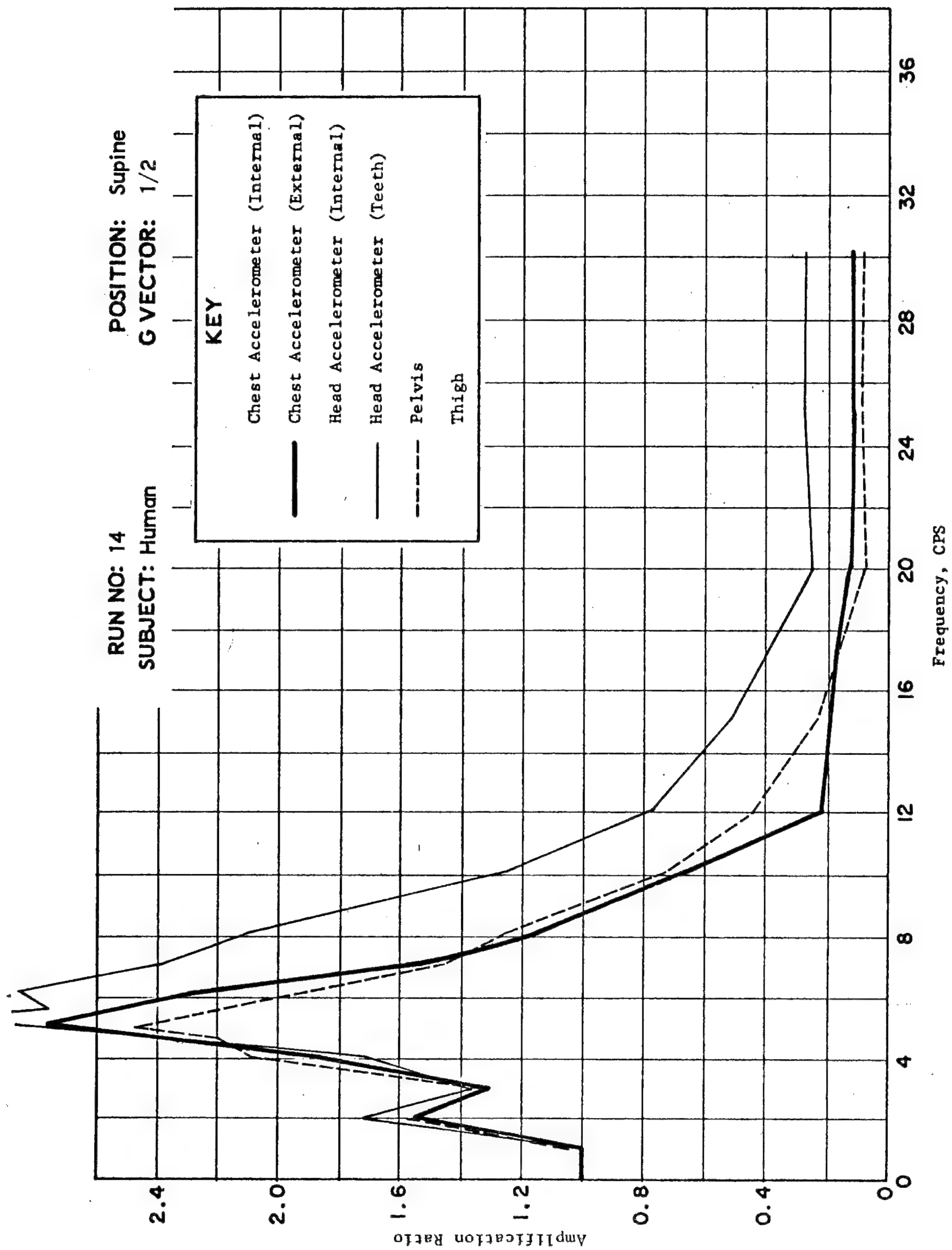


VIBRATION TEST RESULTS

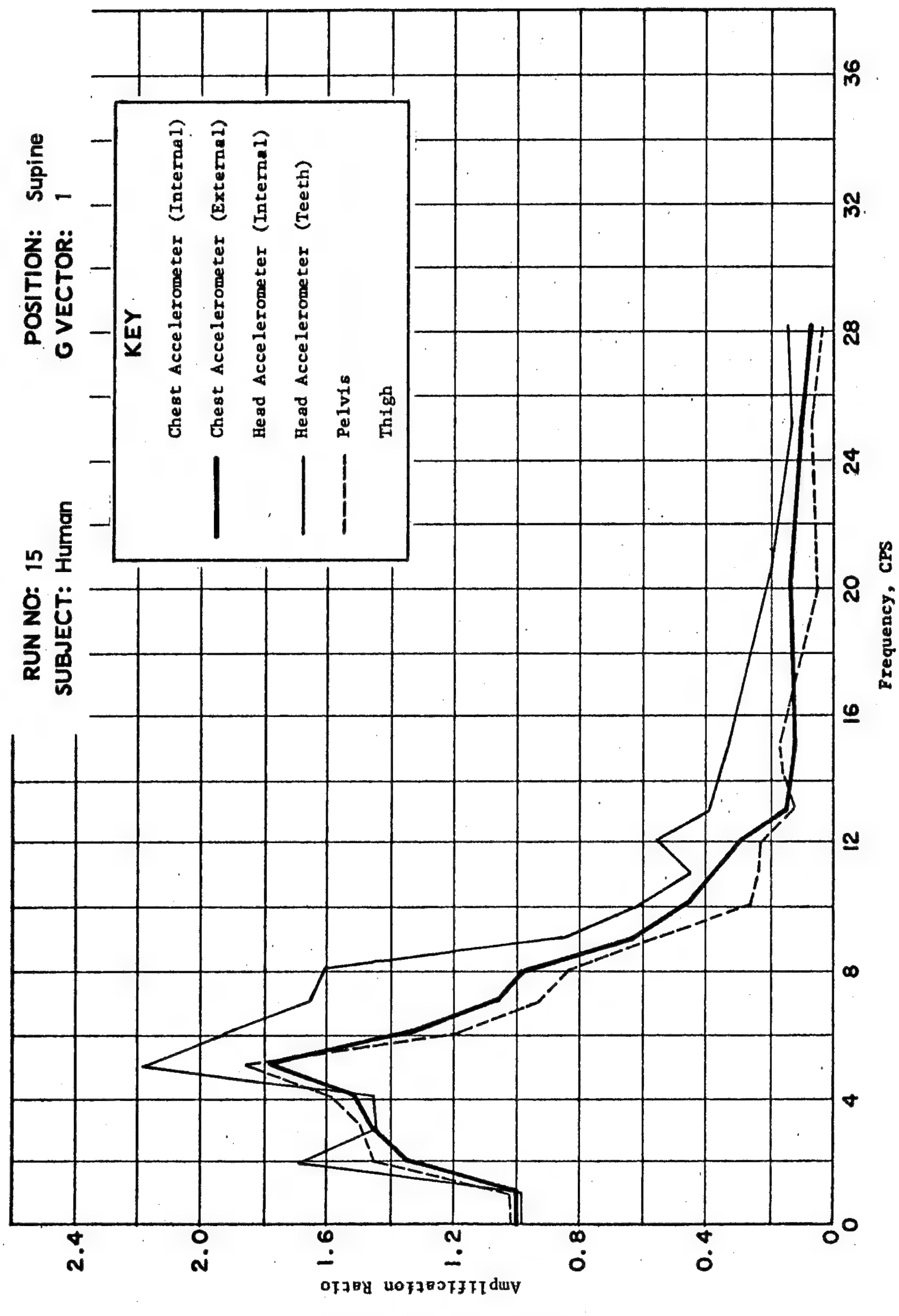
Figure 59



VIBRATION TEST RESULTS
Figure 60



VIBRATION TEST RESULTS
Figure 61



VIBRATION TEST RESULTS

Figure 62

TABLE VI

SUMMARY VIBRATION TEST RESULTS

Seated Subject	G	Transmissibility Ratio Peak			Natural Frequency nf (cps)	Cross Over (cps)	Xmissibility Ratio at 2 nf	Frequency Where Xmissibility Equals 20%
		Head	CH.0	CH.I				
Dummy	1	2.4*	2.25*	2.1*	6.5*	13	1.00	32 at head
Dummy	4	2.0	2.3	2.04	4.25	6	.55	20
		Teeth	Chest	Thigh				
WST	.5	2.95	1.73	1.66	3.75 (teeth 4)	5.5	.65	20
WST	1	2.65	2.45	1.95	3.75	5.5	.5	15
LMM	.5	2.75	2.84	1.9	4.5	7.5	.55	18
LMM	1	2.58*	4.3	2.0*	3.75	5.0	.7	--
LMM	1	4.00	3.00	1.95	4.5	7.0	.6	15
Supine		Head	CH.0	CH.I				
Dummy	1	1.9	3.0*	2.8*	chest 6.5 (head 13.5)	11 (22)	.8 (.56)	34
Dummy	4	(?)	2.28	2.16	6 (head 7*)	8.5	.45	20
		Teeth	Chest	Pelvis				
WST	.5	2.7	2.1	(?)	5.5	9.5	.4	15
WST	1	1.9	1.8	1.8	chest & pel. 4	6.5	.55	14
					(teeth 6)	(9.75)	(.50)	(25)
LMM	.5	3.19	2.94	2.46	5	10.5	.7	16
LMM	1	2.17	1.76	1.84	chest & pel. 5	5.75	.40	12.5
		2.95*			(teeth 6.2)	(8.75)	(.50)	(20)

*extrapolated

E. Shock Test Summary

To simulate shock pulse inputs that would be representative of those encountered under operational conditions, a number of shock pulse shapes and magnitudes were considered. A modified isometric sawtooth pulse shape was selected as shown by the input trace in Figure 63. The typical response trace indicates the acceleration experience of a body segment. Figure 64 shows the subject following a drop in the seated position. Both ISOMODE RUBBER PADS and hemp rope bumpers were used as buffers at the tower base to provide the desired deceleration pulse shape. Maximum velocity change at impact was limited by the 6 foot drop height capability of the tower used for these experiments.

Including calibration tests, a total of 22 test drops were recorded. Maximum input during the dummy test was 36 G with a 35 millisecond pulse duration which indicated a velocity change of 20.0 feet per second, based on a triangular pulse shape. The maximum manned input was 27 G with a 35 millisecond duration which indicated a velocity change of 15.1 feet per second.

The optimum cushion response to a single shock pulse input would be a single acceleration pulse of equal energy, but with a lower acceleration peak and a longer pulse duration. The lower the response acceleration pulse, the greater the physiological protection provided by the cushion.

The optimum response peak would, of course, have no rebound. Tables VIII through XI show the results of the shock tests in summary form.

Typical trace records (actually from the raw data) for the manned and unmanned supine position tests are shown in Figures 65 and 66. The manned and unmanned trace records (actually from the raw data) for the seated position tests are shown in Figures 67 and 68.

The acceleration response traces obtained during the shock tests indicate that the test subject experienced a highly damped oscillation as the result of the impact at the couch base. This oscillation varied in duration from a minimum of .5 cycles to a maximum of 1.5 cycles. Oscillations less than $\pm$ 2 G about the zero G base line were considered physiologically insignificant and therefore omitted during the data reduction.

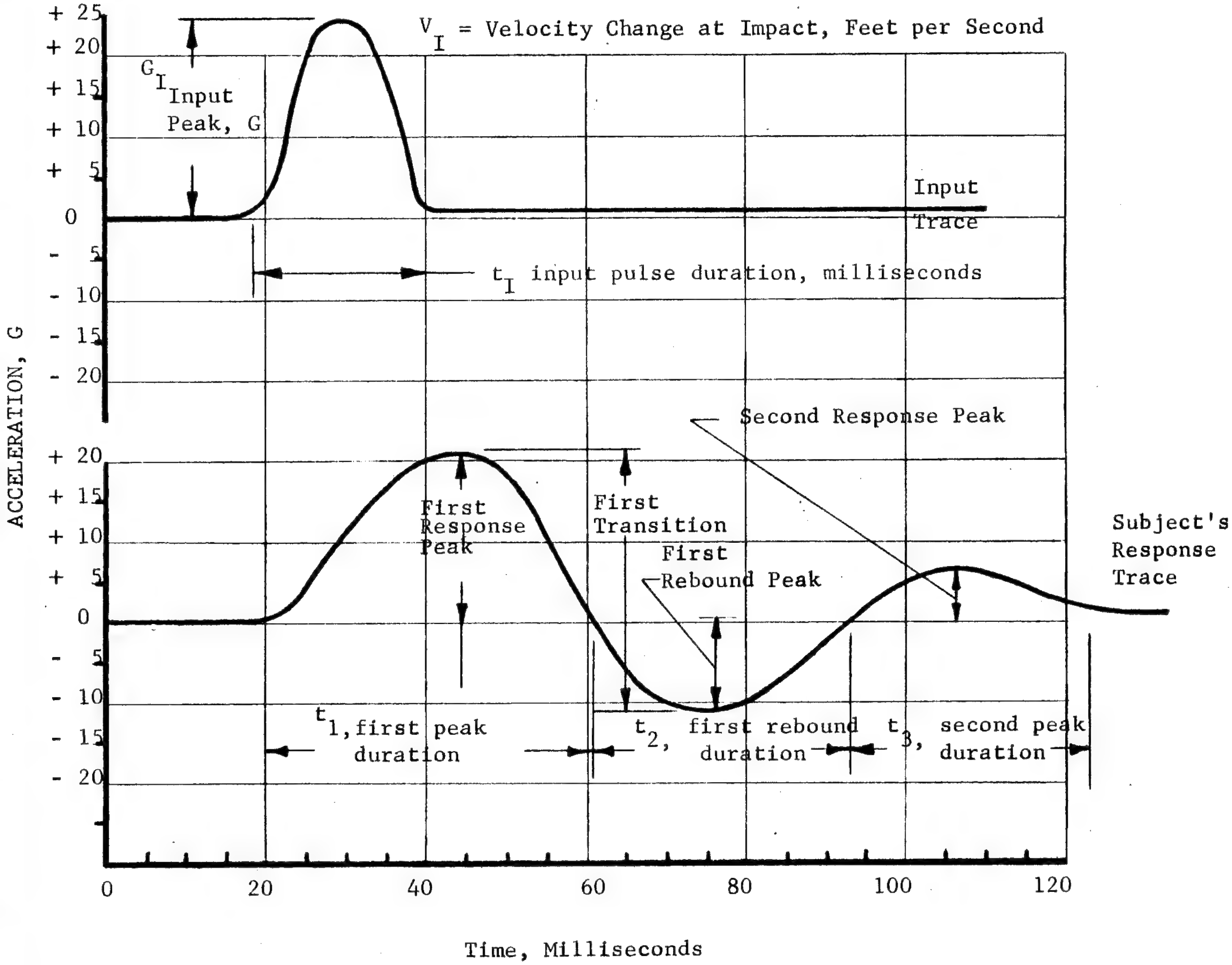
To evaluate the physiological significance of the rapidly damped response traces, two parameters are of prime importance. The first response peak reveals the percentage of the input that is transmitted through the cushion to the subject. The magnitude of the first transition, which is the sum of the first response and the first rebound peaks reveals the maximum rapid acceleration change that the subject experienced.

The magnitude of the first transition reflects both the ability of the cushion to attenuate the initial response peak and the ability of the cushion to absorb energy in reducing rebound. In all cases, rebound was recorded so the ratio of the first transition acceleration magnitude to the peak input acceleration will provide the best indication of the cushion's effectiveness.

For the seated position, the average acceleration amplification ratio for each subject at the first transition ranged from .47 to 1.39. The 1.39 ratio, resulting from a short duration, moderately severe neck whip, was a single isolated occurrence.

The manned seated test results show that the helmet accelerometer consistently recorded higher values than either thigh or chest sensors. In the unmanned seated tests, the dummy's head accelerometer recorded approximately the same values as the other accelerometers.

The supine position tests results indicate an average acceleration amplification ratio range varying from .55 to 1.3.



R_1 = First Peak Cushion Amplification Ratio = First Response Peak $\div$ G_I

R_2 = First Rebound Cushion Amplification Ratio = First Rebound Peak $\div$ G_I

R_3 = Second Peak Cushion Amplification Ratio = Second Response Peak $\div$ G_I

R_t = First Transition Cushion Amplification Ratio = First Transition $\div$ G_I

TYPICAL SHOCK INPUT AND RESPONSE TRACES

FIGURE 63

SHOCK TEST APPARATUS - SEATED POSITION

FIGURE 64

All shock tests were conducted on 4 December 1964. The inputs monitored on the couch are shown on Table VII. Figure 65 illustrates the mounting method on the shock machine.

TABLE VII

SHOCK TEST INPUT TABLE

Trace Number	Test Axis	Required G's	Required MS	Results G's	Results MS	Specimen
1	Supine	10.0	20.0	22.9	29.2	Dummy
2	Supine	10.0	20.0	13.5	25.2	Dummy
3	Supine	10.0	20.0	9.35	26.6	Dummy
4	Supine	10.0	20.0	4.96	25.1	Dummy
5	Supine	10.0	20.0	8.5	- *	Dummy
6	Supine	10.0	20.0	10.45	25.4	Dummy
7	Supine	20.0	40.0	21.9	39.4	Dummy
8	Supine	20.0	40.0	24.0	34.8	Dummy
9	Supine	20.0	40.0	22.2	44.3	Dummy
10	Supine	40.0	40.0	- **	- **	Dummy
11	Supine	40.0	40.0	- **	- **	Dummy
12	Supine	40.0	40.0	31.8	35.4	Dummy
13	Supine	10.0	20.0	10.08	19.5	McClernan
14	Supine	20.0	40.0	21.2	34.0	McClernan
15	Supine	10.0	20.0	10.68	21.5	Thayer
16	Supine	20.0	40.0	19.0	40.03	Thayer
17	Supine	20.0	40.0	19.3	40.04	Thayer
18	Seated	10.0	20.0	10.15	21.3	Dummy
19	Seated	20.0	40.0	21.2	34.6	Dummy
20	Seated	40.0	40.0	27.4	44.8	Dummy
21	Seated	40.0	40.0	31.2	41.04	Dummy
22	Seated	10.0	20.0	8.65	28.2	McClernan
23	Seated	10.0	20.0	12.0	23.4	McClernan
24	Seated	20.0	40.0	15.4	19.65	McClernan
25	Seated	20.0	40.0	20.2	22.4	Thayer
26	Seated	20.30	40.0	27.0	39.8	Thayer

At the conclusion of all testing, the test items were returned to Aircraft Armaments, Inc.

* No Time Record

** Malfunction in Input System

TABLE VIII

SHOCK TEST DATA SUMMARY

DROP NO.	INPUT	SUBJECT RESPONSE							CHANNEL	ACCELEROMETER LOCATION
		PEAK ACCELERATION			PULSE DURATION					
		G_{11}	G_{12}	G_{13}	t_{11}	t_{12}	t_{13}	t_{14}		
		G_{21}	G_{22}	G_{23}	t_{21}	t_{22}	t_{23}	t_{24}		
	G_I t_I V_I	G_{31}	G_{32}	G_{33}	t_{31}	t_{32}	t_{33}	t_{34}		
1	24 - -								4	Couch Base
		.71	.96	.42	40	50	30	120	1	Head Internal
	SUPINE DUMMY	.62	.80	.25	50	130	100	280	2	Chest Internal
		.75	.92	.25	50	130	110	290	3	Chest External
		.69	.89	.30	47	103	80	230		AVERAGE
2	22 22 7.7								4	Couch Base
		.62	.86	.36	40	56	40	136	1	Head Internal
	SUPINE DUMMY	.45	.55	.17	53	110	70	233	2	Chest Internal
		.48	.57	.17	53	120	70	243	3	Chest External
		.52	.66	.23	49	95	60	204		AVERAGE
3	14 28 6.3								4	Couch Base
		.62	.88	.42	40	55	48	143	1	Head Internal
	SUPINE DUMMY	.54	.81	.35	55	70	90	215	2	Chest Internal
		.54	.77	.31	60	65	60	185	3	Chest External
		.57	.82	.36	52	63	66	181		AVERAGE
4	10 32 5.1								4	Couch Base
		.67	1.00	.53	44	50	48	142	1	Head Internal
	SUPINE DUMMY	.56	.83	.33	62	70	100	232	2	Chest Internal
		.61	.89	.39	70	63	89	213	3	Chest External
		.61	.91	.42	59	61	76	196		AVERAGE

KEY

G_I = Input G

t_I = Input Pulse Duration

V_I = Velocity Change at Impact

G_{X1} = 1st Response Peak G

G_{X2} = 1st Transition G

G_{X3} = 2nd Transition G

T_{X1} = 1st Peak Duration

T_{X2} = 1st Rebound Duration

T_{X3} = 2nd Peak Duration

TABLE IX
SHOCK TEST DATA SUMMARY

DROP NO.	INPUT G_I	INPUT t_I	INPUT V_I	PEAK ACCELERATION G_{11} G_{21} G_{31}	G_{12} G_{22} G_{32}	G_{13} G_{23} G_{33}	PULSE DURATION t_{11} t_{21} t_{31}	t_{12} t_{22} t_{32}	t_{13} t_{23} t_{33}	t_{14} t_{24} t_{34}	CHANNEL	ACCELEROMETER LOCATION
5	11	21	3.7								4	Couch Base
				.57	.97	.75	35	45	40		1	Head Internal
	SUPINE DUMMY			.40	.60	.20	50	50	0		2	Chest Internal
				.45	.60	.15	55	50	0		3	Chest External
				.47	.72	.37	47	48	13			AVERAGE
6	24	35	13.5								4	Couch Base
				.75	.92	.29	48	63	48		1	Head Internal
	SUPINE DUMMY			.75	.92	.17	60	68	0		2	Chest Internal
				.87	1.06	.21	50	70	0		3	Chest External
				.79	.97	.22	53	67	16			AVERAGE
7	24	45	17.3								4	Couch Base
				.80	1.02	.37	50	55	40		1	Head Internal
	SUPINE DUMMY			1.09	1.26	.28	70	45	0		2	Chest Internal
				1.09	1.39	.30	50	95	0		3	Chest External
				.99	1.22	.32	57	65	13			AVERAGE
8	26	38	15.8								4	Couch Base
				.72	1.00	.40	50	57	40		1	Head Internal
	SUPINE DUMMY			1.26	1.50	.30	55	70	0		2	Chest Internal
				1.12	1.40	.28	48	85	0		3	Chest External
				1.03	1.30	.33	51	71	13			AVERAGE
9	36	35	20.1								4	Couch Base
				.64	.93	.37	45	57	50		1	Head Internal
	SUPINE DUMMY			.91	1.11	.20	45	80	0		2	Chest Internal
				1.09	1.26	.17	45	80	0		3	Chest External
				.88	1.10	.25	45	72	17			AVERAGE
10	36	32	18.4								4	Couch Base
				.66	.89	.29	45	60	50		1	Head Internal
	SUPINE DUMMY			.91	1.11	.20	45	90	0		2	Chest Internal
				1.06	1.27	.21	43	80	0		3	Chest External
				.88	1.09	.23	44	77	17			AVERAGE
11	11	20	3.5								4	Couch Base
				.30	.45	.15	53	40	0		1	Helmet
	SUPINE HUMAN			.50	1.05	.75	48	60	50		2	Knee
				.40	.50	.15	49	45	60		3	Chest
				.40	.67	.35	50	48	36			AVERAGE

TABLE X

SHOCK TEST DATA SUMMARY

DROP NO.	INPUT	SUBJECT RESPONSE							CHANNEL	ACCELEROMETER LOCATION
		PEAK ACCELERATION			PULSE DURATION					
	G_I t_I V_I	G_{11} G_{21} G_{31}	G_{12} G_{22} G_{32}	G_{13} G_{23} G_{33}	t_{11} t_{21} t_{31}	t_{12} t_{22} t_{32}	t_{13} t_{23} t_{33}	t_{14} t_{24} t_{34}		
12	21 33 11.1								4	Couch Base
		.65	1.30	.90	70	18	38		1	Helmet
	SUPINE HUMAN	.70	1.25	.55	50	60	0		2	Knee
		.90	1.13	.23	55	130	0		3	Chest
		.75	1.23	.56	58	69	13			AVERAGE
13	11 21 3.7								4	Couch Base
		.50	.75	.32	60	30	10		1	Helmet
	SUPINE HUMAN	.22	.42	.20	60	50	0		2	Stomach
		.40	.48	.08	45	45	0		3	Chest
		.37	.55	.20	55	42	33			AVERAGE
14	21 38 12.1								4	Couch Base
		.71	1.29	.57	65	20	5		1	Helmet
	SUPINE HUMAN	.76	.76	-	65	0	0		2	Hip
		1.00	1.00	-	55	0	0		3	Chest
		.82	1.02	.57	62	6.7	1.7			AVERAGE
15	11 21 3.7								4	Input
		.30	.42	.12	60	50	-	110	1	Head Internal
	SEATED DUMMY	.33	.53	.30	55	50	40	145	2	Chest Internal
		.35	.50	.15	57	50	-	107	3	Chest External
		.33	.48	.19	57	50	40	121		AVERAGE
16	21 37 12.4								4	Couch Base
		.52	.71	.19	80	80	-	160	1	Head Internal
	SEATED DUMMY	.62	.75	-	75	-	-	75	2	Chest Internal
		.76	.76	-	76	-	-	76	3	Chest External
		.63	.74	.19	77	80	0	104		AVERAGE
17	31 35 17.4								4	Input
		.50	.73	.23	60	65	-	125	1	Head Internal
	SEATED DUMMY	.93	.93	-	45	-	-	45	2	Chest Internal
		1.43	1.63	.20	45	40	-	95	3	Chest External
		.95	1.10	.22	50	52	-	88		AVERAGE

TABLE XI
SHOCK TEST DATA SUMMARY

DROP NO.	INPUT			SUBJECT RESPONSE							CHANNEL	ACCELEROMETER LOCATION
				PEAK ACCELERATION			PULSE DURATION					
				G_{11} G_{21} G_{31}	G_{12} G_{22} G_{32}	G_{13} G_{23} G_{33}	t_{11} t_{21} t_{31}	t_{12} t_{22} t_{32}	t_{13} t_{23} t_{33}	t_{14} t_{24} t_{34}		
	G_I	t_I	V_I									
18	8	25	3.2								4	Couch Base
				.37	.56	.34	50	40	40		1	Thigh
	SEATED HUMAN			.89	1.19	.30	60	70	0		2	Helmet
				.22	.22	-	80	0	0		3	Chest
				.49	.66	.21	63	37	13			AVERAGE
19	11	22	3.9								4	Couch Base
				.35	.55	.25	60	45	20		1	Thigh
	SEATED HUMAN			.80	1.25	.60	55	70	25		2	Helmet
				.35	.45	.10	70	80	0		3	Chest
				.50	.75	.32	62	65	15			AVERAGE
20	15	23	5.5								4	Couch Base
				.29	.43	.21	60	50	20		1	Thigh
	SEATED HUMAN			.71	1.08	.43	50	80	30		2	Helmet
				.21	.36	.14	70	60	0		3	Chest
				.40	.62	.26	60	63	17			AVERAGE
21	21	20	6.7								4	Couch Base
				.50	.25	-	40	0	0		1	Thigh
	SEATED HUMAN			.50	.70	.25	55	90	25		2	Helmet
				.30	.45	.15	90	70	0		3	Chest
				.65	.47	.20	62	53	8.3			AVERAGE
22	27	35	15.1								4	Couch Base
				.78	.93	.14	50	35	65		1	Thigh
	SEATED HUMAN			2.04	2.33	.30	45	140	0		2	Helmet
				.70	.91	.21	78	120	0		3	Chest
				1.17	1.39	.22	58	98	22			AVERAGE

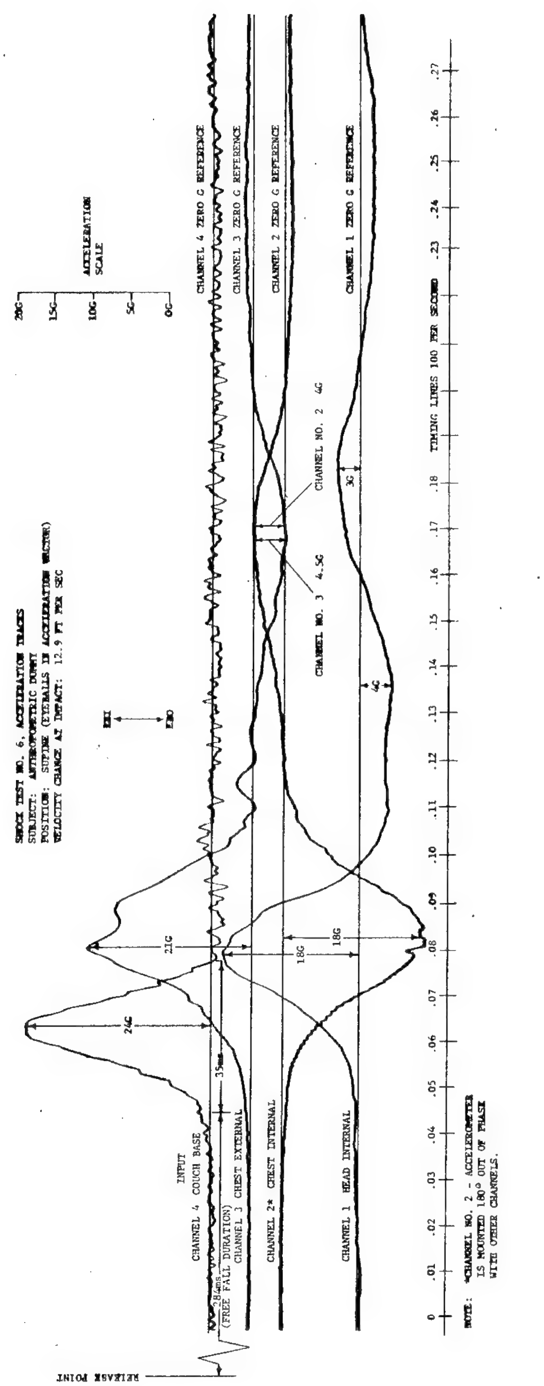

SHOCK TEST NO. 6, ACCELERATION TRACES
SUBJECT: ANTHROPOMETRIC DUMMY
POSITION: SUPINE (EYEBALLS IN ACCELERATION VECTOR)
VELOCITY CHANGE AT IMPACT: 12.9 FT PER SEC
ACCELERATION SCALE
20G
15G
10G
5G
0G
CHANNEL 4 ZERO G REFERENCE
CHANNEL 3 ZERO G REFERENCE
CHANNEL 2 ZERO G REFERENCE
CHANNEL 1 ZERO G REFERENCE
INPUT
CHANNEL 4 COUCH BASE
CHANNEL 3 CHEST EXTERNAL
CHANNEL 2* CHEST INTERNAL
CHANNEL 1 HEAD INTERNAL
284ms (FREE FALL DURATION)
35ms
24G
21G
18G
18G
CHANNEL NO. 3 4.5G
CHANNEL NO. 2 4G
3G
4G
RELEASE POINT
TIMING LINES 100 PER SECOND
0
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10
.11
.12
.13
.14
.15
.16
.17
.18
.23
.24
.25
.26
.27
NOTE: *CHANNEL NO. 2 - ACCELEROMETER IS MOUNTED 180° OUT OF PHASE WITH OTHER CHANNELS.

Figure 65

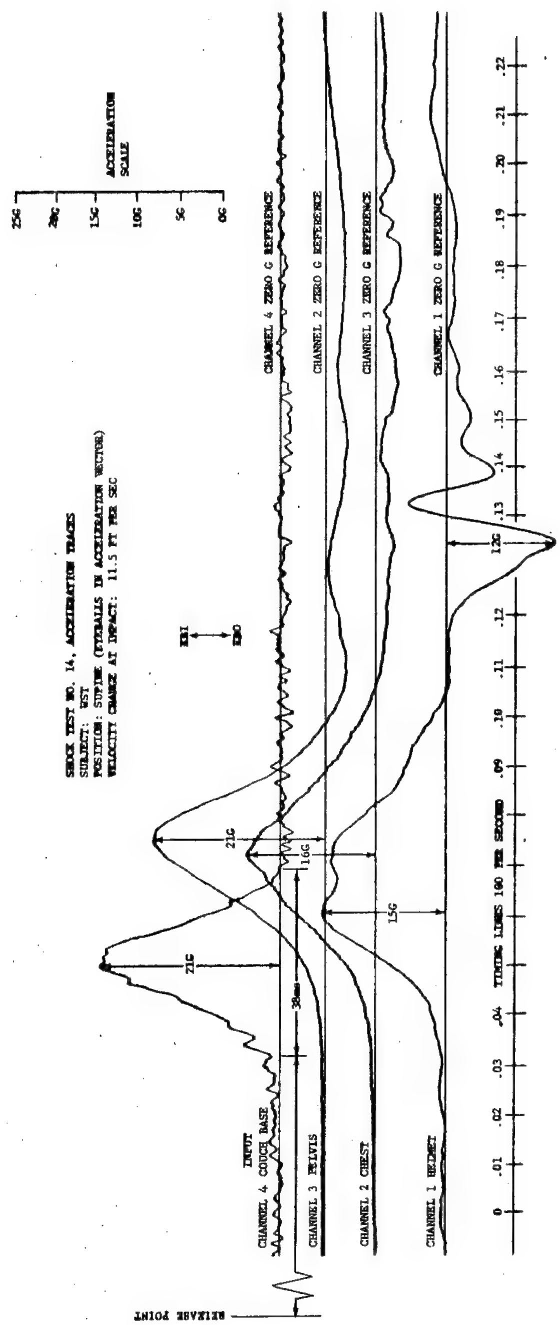

SHOCK TEST NO. 14, ACCELERATION TRACES
SUBJECT: WST
POSITION: SUPINE (EYEBALLS IN ACCELERATION VECTOR)
VELOCITY CHANGE AT IMPACT: 11.5 FT PER SEC
ACCELERATION SCALE
25G
20G
15G
10G
5G
0G
CHANNEL 4 ZERO G REFERENCE
CHANNEL 2 ZERO G REFERENCE
CHANNEL 3 ZERO G REFERENCE
CHANNEL 1 ZERO G REFERENCE
INPUT
CHANNEL 4 COUCH BASE
CHANNEL 3 PELVIS
CHANNEL 2 CHEST
CHANNEL 1 HELMET
RELEASE POINT
21G
21G
16G
15G
12G
38ms
TIMING LINES 100 PER SECOND
0 .01 .02 .03 .04 .09 .10 .11 .12 .13 .14 .15 .16 .17 .18 .19 .20 .21 .22

Figure 66

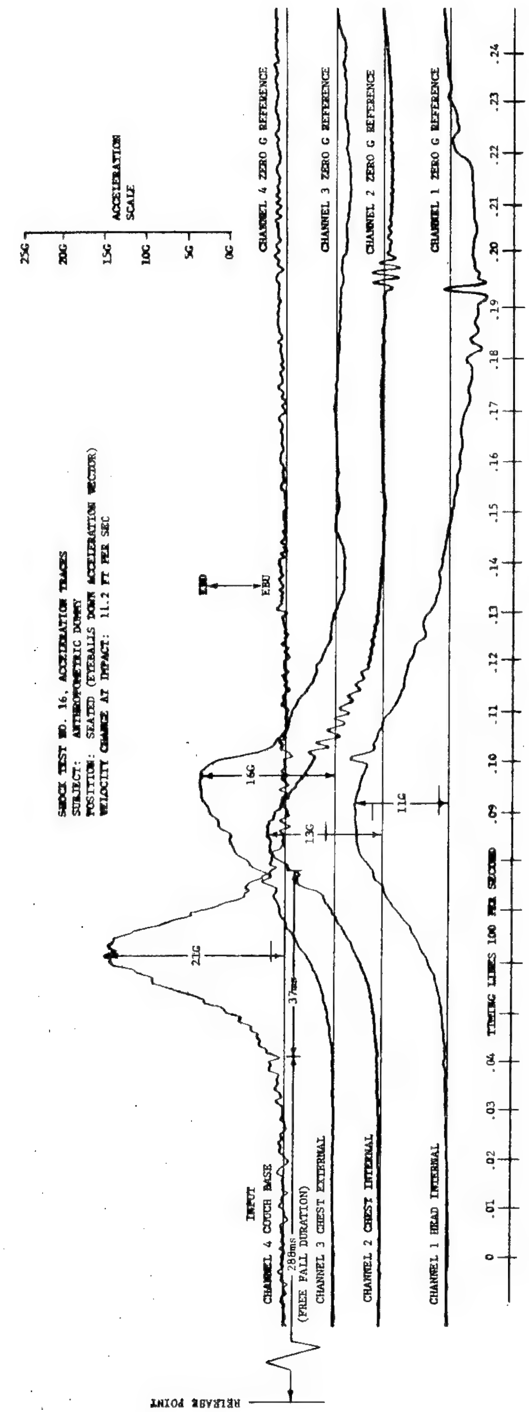

SHOCK TEST NO. 16, ACCELERATION TRACES
SUBJECT: ANTHROPOMETRIC DUMMY
POSITION: SEATED (EYEBALLS DOWN ACCELERATION VECTOR)
VELOCITY CHANGE AT IMPACT: 11.2 FT PER SEC
ACCELERATION SCALE
25G
20G
15G
10G
5G
0G
INPUT
CHANNEL 4 COUCH BASE
CHANNEL 3 CHEST EXTERNAL
CHANNEL 2 CHEST INTERNAL
CHANNEL 1 HEAD INTERNAL
CHANNEL 4 ZERO G REFERENCE
CHANNEL 3 ZERO G REFERENCE
CHANNEL 2 ZERO G REFERENCE
CHANNEL 1 ZERO G REFERENCE
288ms
(FREE FALL DURATION)
RELEASE POINT
37ms
21G
16G
13G
11G
EBU
EBD
TIMING LINES 100 PER SECOND
0
.01
.02
.03
.04
.09
.10
.11
.12
.13
.14
.15
.16
.17
.18
.19
.20
.21
.22
.23
.24

Figure 67

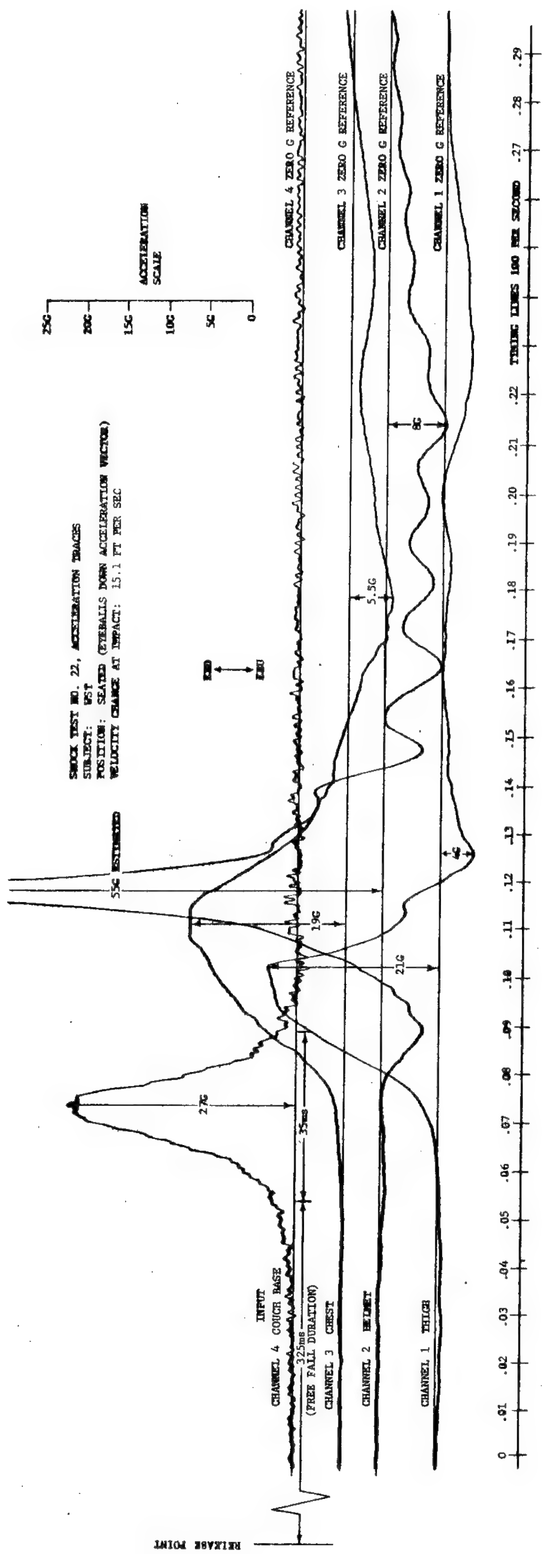

SHOCK TEST NO. 22, ACCELERATION TRACES
SUBJECT: WST
POSITION: SEATED (EYEBALLS DOWN ACCELERATION VECTOR)
VELOCITY CHANGE AT IMPACT: 15.1 FT PER SEC
ACCELERATION SCALE
25G
20G
15G
10G
5G
0
CHANNEL 4 ZERO G REFERENCE
CHANNEL 3 ZERO G REFERENCE
CHANNEL 2 ZERO G REFERENCE
CHANNEL 1 ZERO G REFERENCE
TIMING LINES 100 PER SECOND
INPUT
CHANNEL 4 COUCH BASE
325ms
(FREE FALL DURATION)
CHANNEL 3 CHEST
CHANNEL 2 HELMET
CHANNEL 1 THIGH
RELEASE POINT
35ms
27G
21G
19G
55G ESTIMATED
5.5G
8G

Figure 68

IV. ACCELERATION TESTS

Acceleration tests were conducted in the World's Largest Human Centrifuge at the Aviation Medical Acceleration Laboratory, Naval Air Development Center, Johnsville, Pennsylvania. Tests were conducted in the $+G_x$ and $+G_z$ vectors, EBI and EBD respectively. During these tests, a seven-channel oscilloscograph record was made which included the four deflection sensor inputs plus the three components of acceleration at the end of the centrifuge arm.

Twelve subjects rode the couch during the acceleration testing. Three were AAI employees, inexperienced in G, and nine were experienced AMAL personnel. All subjects were given thorough pre-test medical examinations of the Category I Flight Physical type, plus diagnostic A-P spinal X-rays and diagnostic EKG's. Immediately preceding a given subject's run, the Facility Medical Officer monitored blood pressure, pulse, respiration, heart sound and EKG. EKG and respiration were monitored during the G runs. The subjects' height, weight and age are shown in Table XII.

Four of the subjects had G experience in other couches and were able to evaluate the foam couch comparatively. The three AAI subjects rode the couch in $+G_z$ and $+G_x$ on scheduled runs and then rode the couch at $+3G_x$ and $+5G_x$ for longer periods to better evaluate suggested design improvements.

The acceleration was presented in a haversine input with a 12.6 second ramp, a 5 second peak duration and a 12.6 second haversine decay. All subjects were tested to the limit of physiological endurance (at least blackout, in some cases, momentary unconsciousness) in the $+G_z$ mode. All subjects but two were tested to $+10G_x$. One subject went to physiological tolerance at $+12G_x$ (greyout) and one subject was stopped at $+5G_x$ for medical reasons not related to the couch configuration.

The $+G_x$ vector was presented at levels of 3, 5, 7 and 10G with one minute rests between runs. The $+G_z$ was presented at levels of 3, 4, 5 and 6 with rest times at the discretion of the subject.

A triaxial accelerometer pack rigidly mounted at the back of the couch provided acceleration reference information. The three accelerometer traces plus the four deflection sensor traces were recorded on a seven channel recorder so that the performance of the couch could be evaluated from a single time reference. A typical acceleration trace record is shown in Figure 69.

Two sets of coordinate axes about the subjects' CG were used to describe the acceleration vectors received. Figure 70 shows the X_1, Y_1, Z_1 axes used for the EYE BALLS DOWN Tests. As shown in Figure 70, the axes of the accelerometer pack were coincident with the X_1, Y_1, Z_1 axes.

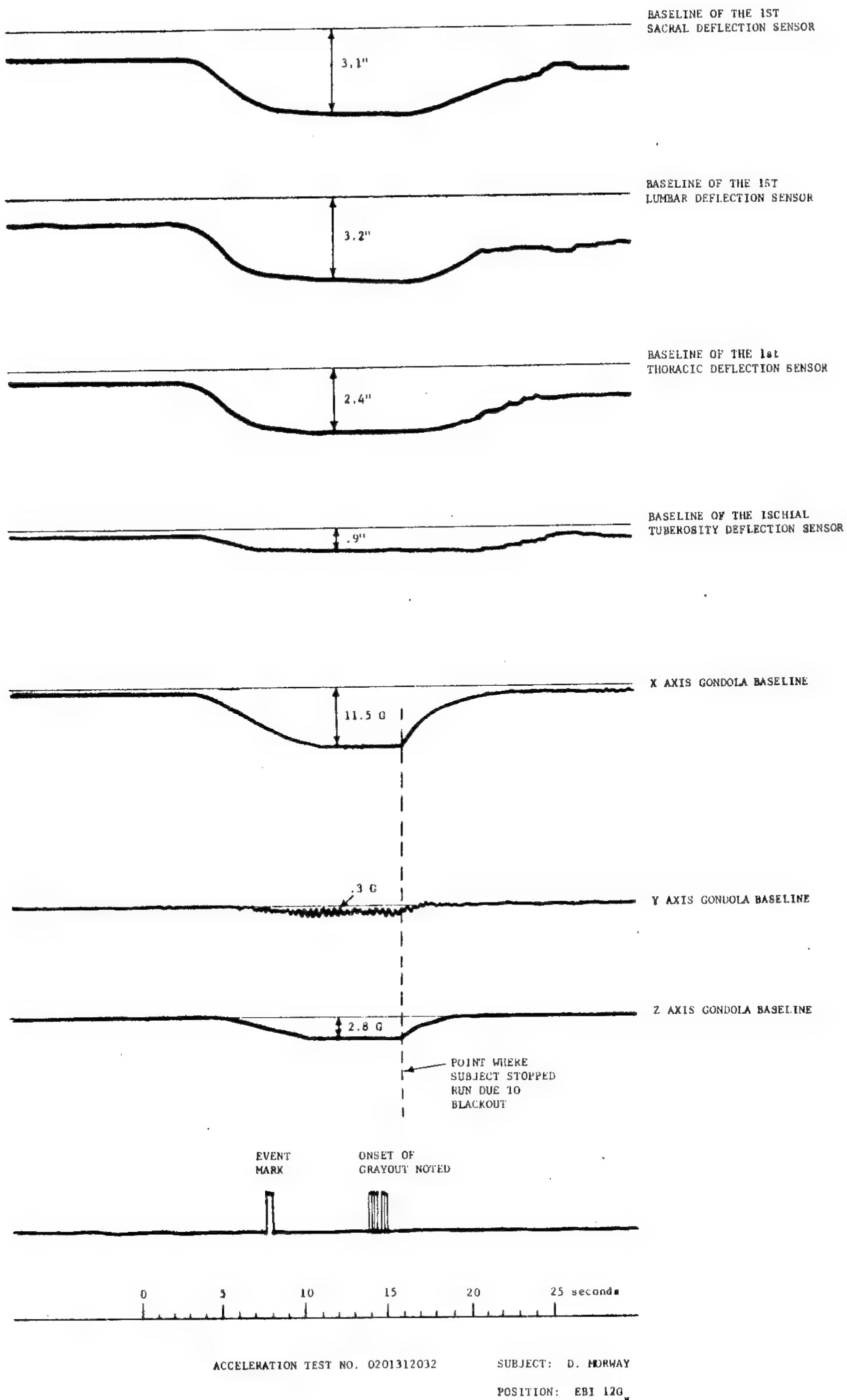
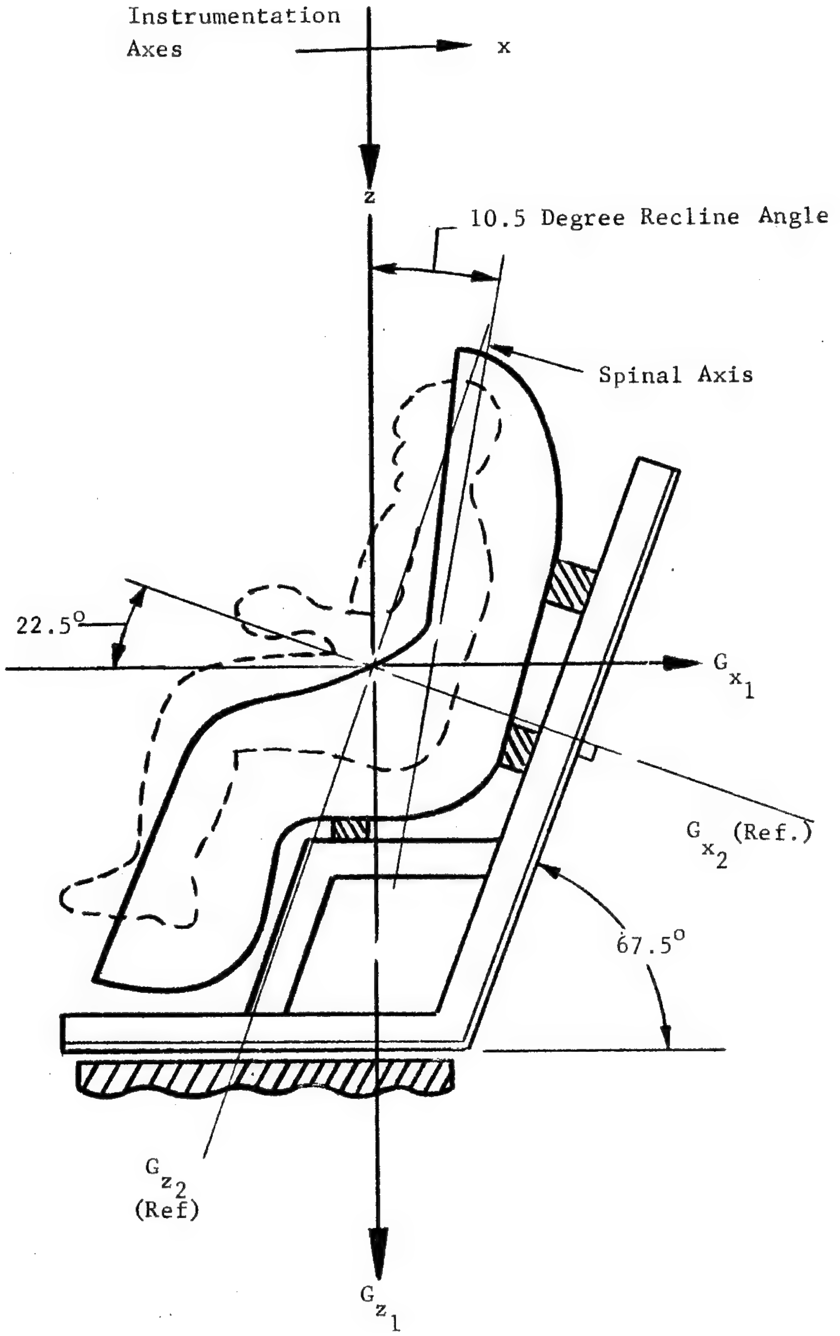

BASELINE OF THE 1ST
SACRAL DEFLECTION SENSOR
3.1"
BASELINE OF THE 1ST
LUMBAR DEFLECTION SENSOR
3.2"
BASELINE OF THE 1st
THORACIC DEFLECTION SENSOR
2.4"
BASELINE OF THE ISCHIAL
TUBEROSITY DEFLECTION SENSOR
.9"
X AXIS GONDOLA BASELINE
11.5 G
.3 G
Y AXIS GONDOLA BASELINE
Z AXIS GONDOLA BASELINE
2.8 G
POINT WHERE
SUBJECT STOPPED
RUN DUE TO
BLACKOUT
EVENT
MARK
ONSET OF
GRAYOUT NOTED
0
5
10
15
20
25 seconds
ACCELERATION TEST NO. 0201312032
SUBJECT: D. MORWAY
POSITION: EBI 12Gx

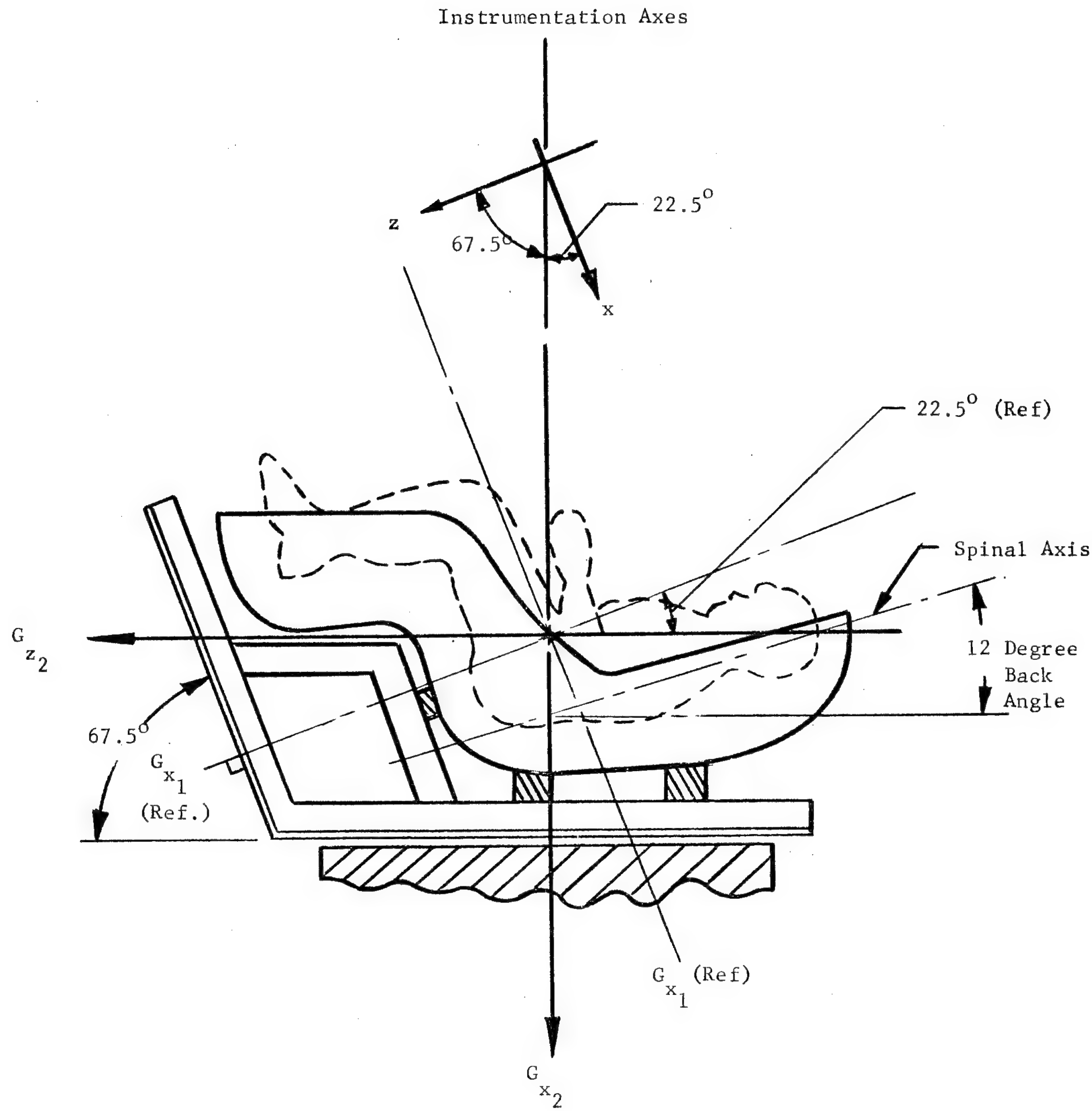
FIGURE 69



EYE BALLS DOWN TEST POSITION

Acceleration Input Vector is Coincident With G_{z_1}

Figure 70



EYE BALLS IN TEST POSITION

Acceleration Input Vector is Coincident With G_{x_2}

Figure 71

The X_2, Y_2, Z_2 coordinate axes used to describe the acceleration vectors in the EYEBALLS IN Tests are shown in Figure 71. As shown in Figure 71 the angle between the X_2, Z_2 axes and the XZ instrumentation axes is 22.5°.

For the EBD tests, the acceleration vector received can be measured directly from the Z axis accelerometer of the instrument pack. For the EBI tests, the following formula is used to convert from the X and Z axis accelerometer measurements to the X_2 acceleration vector input.

$$\Delta X \text{ (secant } 22.5^{\circ}) = \Delta X_2$$

where

ΔX = change in recorded acceleration level for the X axis.

secant 22.5° = 1.0824

ΔX_2 = change in X_2 axis acceleration vector.

The results of the acceleration tests are shown in Tables XIII through XIX.

The recording potentiometers for cushion deflection were located approximately behind the first sacral vertebra (S-1), the first lumbar vertebra (L-1) and the first thoracic vertebra on the back, and under the right ischial tuberosity (IT). A summary of the cushion deflection information is presented in Table XX, and a plot of the deflection versus G is shown in Figure 70 for both $+G_x$ and $+G_z$. It will be noted that sensors 1, 2, 3, and 3 HEL are applicable for $+G_x$ and sensor 4 is applicable for $+G_z$.

Nine tests were made with channel 3 sensor located behind the helmet as shown in Column 3 (HEL).

The test subjects reported that the seat pocket formed by the sides of the couch provided firm support at the sides of the torso. In addition to providing lateral protection, the pocket significantly reduced the tendency of the viscera to spread sideward at high acceleration levels.

Due primarily to the side support of the pocket, the deflection sensors showed that the subject failed to return precisely to his original position following a high G experience. Permanent deformations of several tenths of an inch up to .6 inches were recorded following a test series.

The $+G_x$ (EBI) series test results summarized in Table XX and Figure 70 show that the Channel 1, 2, and 3 deflection sensors gave nearly equivalent results which followed the characteristic cushion deflection curve previously cited and included here again for comparison, Figure 73. The Channel 4 sensor in the seat indicates that following the initial $+1G_x$ deflection, very little seatward motion occurs with increases in the $+G_x$ vector.

The data indicates that a high G (+ $7G_x$ and $10G_x$) the normal lumbar curve tended to flatten in spite of the curvature built into the cushion.

When subjected to $+G_z$ acceleration, the test subject strained against his restraint system to such an extent that very little depression of the cushion is noted except on the seat. Although there was a sizeable $+G_x$ component presented, the subject stopped himself from moving back into the couch by straining forward, supporting himself on his elbows, shoulder straps, and feet.

The data collected from between run recordings of subject comments and from the past run questionnaire are summarized in the following excerpts from the raw data. The following excerpts are from the tape of the first manned dynamic G run in the Universal Couch. The series ran from $3G_x$ to $12G_x$ (EBI) (input 2.58 - 10.94 G_x and 1.60 - 4.80 G_z). The subject greyed out at $12G_x$ due to 4.80 G_z component.

The following day the subject underwent G_z (EBD) and blacked out at 2.3 G_x and 4.40 G_z.

Included after the two runs, as recorded on the tapes, is a sample questionnaire filled in by the subject before and after the first dynamic run.

TABLE XII

CENTRIFUGE TEST SUBJECT ANTHROPOMETRIC DATA SUMMARY

	Subject	Height	Weight	Age
1.	Tha	70"	183 Lbs.	28 Years
2.	McC	71"	186	32
3.	Kin	73"	170	33
4.	Mor *	67"	150	31
5.	Orr	70"	140	25
6.	Hop *	69"	145	30
7.	Cro	69"	138	30
8.	Har	75"	168	26
9.	Don *	70"	150	36
10.	Lew	64.5"	145	30
11.	Kin	68.5"	167	30
12.	Cha *	71.5"	190 Lbs.	37 Years

Range:

Age	25 - 37 years
Weight	138 - 190 pounds
Height	64.5" to 75"

Average Age - 30 Years   Average Height - 69.8 Inches   Average Weight - 161 Pounds

STATIC TEST ONLY

Subject	Height	Weight	Age
Hal	74.5"	285 Lbs.	33 Years

* Experienced Subjects

TABLE XIII
ACCELERATION TEST RESULTS

Run Number	Subject	"G" Test Level	Instrumentation Axis Acceleration "Divisions"			Computed Seat Axis Acceleration G		Total Deflection, Inches			
			X	Y	Z	G_{X2}	G_{Z1}	1	2	3	4
0100203012	Dummy	$1G_{x2}$	2.50	25.0	1.5			.20	.80	1.10	1.20
		$3G_{x2}$	6.50	26.5	5.0	3.2		.55	1.35	1.65	1.15
5013		$1G_{x2}$	2.50	25.0	1.5			.40	1.00	1.30	1.10
		$5G_{x2}$	11.0	26.0	8.0	5.6		1.10	2.00	2.30	1.20
7014		$1G_{x2}$	2.50	25.0	1.5			.50	1.20	1.40	1.10
		$7G_{x2}$	15.0	26.5	12.0	7.8		1.60	2.50	2.70	1.20
10015		$1G_{x2}$	2.50	25,0	1.5			.65	1.30	1.55	1.10
		$10G_{x2}$	21.5	28.0	18.0	11.3		2.05	2.85	2.90	1.20
15016		$1G_{x2}$	2.50	25.0	1.0			1.05	1.60	1.85	1.00
		$15G_{x2}$	30.0	28.5	27.0	16.0		2.50	3.30	3.05	1.00
20017		$1G_{x2}$	2.5	25.0	1.0			1.10	1.65	1.85	1.00
		$20G_{x2}$	43.0	33.0	39.0	23.0		2.75	3.70	3.20	1.05
25018		$1G_{x2}$	1.0	25.0	0.0			1.20	1.70	1.85	1.05
		$25G_{x2}$	24.0	34.0	22.0	26.0		2.80	3.80	3.25	1.05
30019		$1G_{x2}$	1.0	25.0	0.0			1.30	1.80	1.90	1.10
		$30G_{x2}$	28.0	36.0	26.5	30.2		3.00	4.00	3.30	1.10
30020	(Repeat of 30019)							1.70	2.20	1.40	0.0
0100253021	Dummy	$1G_{z1}$	0.5	25.0	2.0			1.00	1.40	1.40	1.05
		$3G_{z1}$	1.0	26.0	7.0		3.0	1.00	1.45	1.40	1.40
4022		$1G_{z1}$	0.5	25.0	2.0			.95	1.40	1.35	1.30
		$4G_{z1}$	1.0	25.0	9.0		3.8	1.00	1.45	1.35	1.70
5023		$1G_{z1}$	0.5	24.5	2.0			.90	1.40	1.30	1.45
		$5G_{z1}$	1.0	25.0	12.0		5.0	.90	1.45	1.30	1.90
6024		$1G_{z1}$	0.5	24.0	2.0			.90	1.35	1.20	1.50
		$6G_{z1}$	1.0	26.0	14.5		6.0	.90	1.50	1.20	2.10
7025		$1G_{z1}$	0.5	25.0	2.0			.85	1.35	1.15	1.60
		$7G_{z1}$	1.0	26.5	17.0		7.0	.85	1.50	1.20	2.30
60026		$1G_{z1}$	0.5	24.5	2.0			.80	1.35	1.10	1.75
		$10G_{z1}$	1.0	26.5	24.5		10.0	.70	1.50	1.10	2.60
65027		$1G_{z1}$	0.5	24.5	2.0			.75	1.35	1.10	1.90
		$15G_{z1}$	1.0	28.0	34.0		13.8	.50	1.50	1.10	3.05

TABLE XIV
ACCELERATION TEST RESULTS

Run Number	Subject	"G" Test Level	Instrumentation Axis Acceleration "Divisions"			Seat Axis Acceleration G		Total Deflection, Inches			
			X	Y	Z	G_{X2}	G_{Z1}	1	2	3	4
0201303028	Morway	$1G_{x2}$	7.0	25.0	3.5			1.70	1.60	1.30	.85
		$3G_{x2}$	11.0	25.5	5.0	3.2		2.60	2.70	2.15	1.20
5029		$1G_{x2}$	7.0	25.0	3.5			1.80	1.70	1.40	.95
		$5G_{x2}$	14.5	26.0	6.5	5.1		3.40	3.60	2.90	1.45
7030		$1G_{x2}$	7.0	25.0	3.0			2.00	1.90	1.50	1.00
		$7G_{x2}$	18.0	26.5	8.0	7.0		3.90	3.90	3.20	1.60
10031		$1G_{x2}$	7.0	25.0	3.5			1.90	2.00	1.50	1.05
		$10G_{x2}$	24.0	27.5	11.0	10.2		4.20	4.10	3.30	1.60
12032		$1G_{x2}$	7.0	25.0	3.5			2.10	2.00	1.50	1.00
		$12G_{x2}$	28.0	28.0	13.0	12.4		4.20	4.10	3.40	1.60
0209303033	Kinkade	$1G_x$	7.0	25.0	3.0			1.30	2.00	1.40	1.75
		$3G_x$	11.0	25.5	5.0	3.2		2.15	3.10	2.30	1.85
5034		$1G_x$	7.0	25.0	3.5			1.40	2.30	1.60	1.60
		$5G_x$	15.0	26.0	6.5	5.4		3.00	3.90	3.00	1.90
7035		$1G_x$	7.0	25.0	3.5			1.65	2.55	1.80	1.70
		$7G_x$	19.0	27.0	8.5	7.5		3.50	4.20	3.25	2.00
10036		$1G_x$	7.0	25.0	3.5			1.90	2.80	1.90	1.85
		$10G_x$	24.5	28.0	11.0	10.5		3.90	4.50	3.40	2.05
0302353057	Orrick	$1G_z$	5.5	25.0	7.5			1.00	1.20	.90	1.60
		$3G_z$	6.0	25.0	12.0		2.8	1.05	1.45	.90	2.30
4038		$1G_z$	5.0	25.0	7.0			1.00	1.10	.90	1.70
		$4G_z$	5.5	25.0	14.5		4.0	1.00	1.70	.90	2.50
5039		$1G_z$	5.0	25.0	7.0			.90	1.20	.90	1.90
		$5G_z$	5.5	25.0	16.5		4.8	.90	1.60	.80	2.70
6040		$1G_z$	5.0	25.0	7.0			1.00	1.30	.80	1.90
		$6G_z$	6.0	25.0	19.0		5.8	1.00	2.00	.80	2.70
0307353041	Thayer	$1G_z$	6.0	25.0	7.5			.85	1.20	.90	1.40
		$3G_z$	6.0	25.0	12.0		2.8	.85	1.80	.85	2.00
4042		$1G_z$	6.0	25.0	7.0			.85	1.20	.85	1.70
		$4G_z$	6.0	25.0	14.5		4.0	.95	2.10	1.00	2.25
5043		$1G_z$	6.0	25.0	7.0			.85	1.25	.85	1.80
		$5G_z$	6.0	25.0	17.0		5.0	1.10	2.35	1.15	2.50

TABLE XV
ACCELERATION TEST RESULTS

Run Number	Subject	"G" Test Level	Instrumentation Axis Acceleration "Divisions"			Seat Axis Acceleration G		Total Deflection, Inches			
			X	Y	Z	G_{X_2}	G_{Z_1}	1	2	3	4
6044		$1G_Z$	6.0	25.0	7.0			.85	1.20	.85	1.90
		$6G_Z$	6.0	25.5	19.5		6.0	1.25	2.40	.95	2.80
0308303045	McClernan	$1G_X$	7.0	25.5	6.0			1.30	1.30	1.20	.80
		$3G_X$	12.0	26.0	7.0	3.8		2.50	2.70	2.40	1.15
5046		$1G_X$	8.0	25.0	6.0			1.50	1.50	1.20	1.10
		$5G_X$	16.0	26.0	9.0	5.4		3.10	3.45	2.90	1.50
7047		$1G_X$	8.0	25.5	6.0			1.90	2.05	1.50	1.10
		$7G_X$	20.0	27.0	10.5	7.5		3.50	3.70	3.10	1.60
10048		$1G_X$	8.0	25.5	6.0			2.10	2.20	1.60	1.10
		$10G_X$	26.0	28.0	13.0	10.8		3.60	4.00	3.20	1.55
0309353049	Kinkade	$1G_Z$	6.0	25.0	7.0			1.00	1.40	.90	1.70
		$3G_Z$	6.0	25.0	12.0		3.0	1.20	1.80	1.00	2.10
4050		$1G_Z$	6.0	25.0	7.0			1.00	1.35	.90	1.80
		$4G_Z$	6.0	25.5	14.5		4.0	1.30	2.10	1.05	2.40
5051		$1G_Z$	6.0	25.0	7.0			1.00	1.35	.90	1.95
		$5G_Z$	6.0	25.5	16.5		4.8	1.65	2.60	1.15	2.65
0304303052	Donaghy	$1G_X$	8.0	25.0	5.0			.90	1.60	1.10	.65
		$3G_X$	12.0	26.0	7.0	3.2		1.25	2.90	2.30	.80
5053		$1G_X$	8.0	25.0	5.0			1.00	2.10	1.45	.50
		$5G_X$	16.0	26.0	8.5	5.4		1.70	3.55	2.85	.85
7054		$1G_X$	8.0	25.0	5.0			1.05	2.10	1.50	.60
		$7G_X$	20.0	26.0	10.0	7.5		2.20	3.60	3.05	1.20
10055		$1G_X$	8.0	25.0	5.0			1.00	1.90	1.60	.65
		$10G_X$	26.0	28.0	13.0	10.8		1.95	3.70	3.30	1.05
0303353056	Hoppin	$1G_X$	6.0	25.0	7.0			.80	1.20	.70	1.45
		$3G_Z$	6.5	25.0	11.5		2.8	.80	1.50	.95	1.60
4057		$1G_Z$	6.5	25.0	7.0			.80	1.30	.70	1.35
		$4G_Z$	7.0	25.5	14.0		3.8	.80	1.60	1.20	1.55
5058		$1G_Z$	6.5	25.0	7.0			.80	1.30	.75	1.40
		$5G_Z$	7.0	26.0	17.0		5.0	.80	1.90	1.20	1.90

TABLE XVI
ACCELERATION TEST RESULTS

Run Number	Subject	"G" Test Level	Instrumentation Axis Acceleration "Divisions"			Seat Axis Acceleration G		Total Deflection, Inches			
			X	Y	Z	G_{X2}	G_{Z1}	1	2	3	4
0306303059	Harpel	$1G_x$	8.5	25.5	5.0			1.45	1.70	.80	1.10
		$3G_x$	12.5	26.0	7.0	3.2		2.20	2.95	2.00	1.30
5060		$1G_x$	8.5	25.0	5.0			1.70	2.00	1.00	1.10
		$5G_x$	16.0	25.0	8.5	5.1		2.90	3.80	2.70	1.35
7061		$1G_x$	8.0	25.0	5.0			1.90	2.50	1.20	1.10
		$7G_x$	20.0	26.5	10.0	7.5		3.15	4.10	2.90	1.30
10062		$1G_x$	8.0	25.0	5.0			2.00	2.65	1.25	1.00
		$10G_x$	26.0	27.5	13.0	10.8		3.50	4.30	3.10	1.30
0301353063	Morway	$1G_z$	6.5	25.5	7.0			.85	1.10	.60	1.70
		$3G_z$	7.0	25.5	12.0		3.0	.90	1.60	.55	2.30
4064		$1G_z$	6.5	25.5	7.0			.90	1.20	.55	2.00
		$4G_z$	7.0	26.0	14.0		3.8	.90	1.70	.55	2.45
(4-1/2)065		$1G_z$	6.5	25.5	7.0			.90	1.20	.55	2.05
		$4.5G_z$	7.0	26.0	15.5		4.4	.90	1.80	.55	2.50
04 03066	Orrick	$1G_x$	7.0	25.5	7.0			1.70	1.70	1.50	1.50
		$3G_x$	11.0	26.0	10.0	3.2		2.60	2.60	2.00	1.85
5067		$1G_x$	7.5	26.0	7.0			1.80	1.90	1.50	1.55
		$5G_x$	15.0	27.0	14.0	5.6		3.40	3.55	2.75	2.20
7068		$1G_x$	7.5	26.0	7.5			2.10	2.10	1.60	1.60
		$7G_x$	19.0	27.0	17.0	7.3		3.50	3.90	3.20	1.90
0407303069	Thayer	$1G_x$	7.5	26.0	7.0			1.30	1.50	1.20	1.80
		$3G_x$	11.5	26.5	10.0	3.2		1.90	2.45	1.85	2.00
5070		$1G_x$	7.5	26.0	7.0			1.45	1.70	1.20	1.80
		$5G_x$	15.0	26.5	13.5	5.1		3.05	3.40	2.40	2.30
7071		$1G_x$	7.5	26.0	7.0			1.50	1.80	1.20	1.75
		$7G_x$	19.0	27.0	17.0	7.3		3.25	3.65	2.80	2.40
10072		$1G_x$	7.5	26.0	7.0			1.60	1.90	1.20	1.75
		$10G_x$	25.0	28.0	22.0	10.5		3.65	4.05	3.06	2.30

TABLE XVII
ACCELERATION TEST RESULTS

Run Number	Subject	"G" Test Level	Instrumentation Axis Acceleration "Divisions" X	Y	Z	Seat Axis Acceleration G G_{X_2}	G_{Z_1}	Total Deflection, Inches 1	2	3	4
0408353073	McClernan	$1G_z$	5.5	26.0	10.0			1.80	1.50	1.05	2.50
		$3G_z$	6.0	26.0	20.0		3.0	2.00	2.30	1.25	3.10
4074		$1G_z$	5.5	25.5	10.0			1.80	1.60	1.05	2.70
		$4G_z$	6.0	26.0	25.0		4.0	2.10	2.55	1.25	3.50
(4-1/2)075		$1G_z$	5.5	26.0	10.0			1.80	1.60	1.05	2.95
		$4.5G_z$	6.0	26.0	27.0		4.4	2.10	2.40	1.35	3.70
5076		$1G_z$	5.5	25.5	10.0			1.80	1.55	1.05	2.95
		$.5G_z$	6.0	26.0	29.0		4.8	2.00	2.30	1.60	3.75
0410303077	Crossan	$1G_X$	8.0	26.0	7.0			1.80	1.40	1.40	1.60
		$3G_X$	12.0	26.0	10.0	3.2		2.70	2.05	1.90	1.95
5078		$1G_X$	8.0	25.5	7.0			2.00	1.60	1.40	1.60
		$5G_X$	15.5	26.5	13.0	5.1		3.40	3.10	2.60	2.10
7079		$1G_X$	8.0	25.5	7.0			2.20	1.70	1.35	1.50
		$7G_X$	19.5	27.0	17.0	7.3		3.70	3.50	2.95	2.00
040 03080	Hoppin	$1G_X$	8.0	26.0	7.0			1.25	2.00	1.00	1.35
		$3G_X$	12.0	26.0	10.0	3.2		1.60	2.75	1.60	1.60
5081		$1G_X$	8.0	25.5	7.0			1.30	2.10	1.10	1.40
		$5G_X$	16.0	26.5	13.0	5.1		2.40	3.55	2.10	1.90
7082		$1G_X$	8.0	26.0	7.0			1.40	2.30	1.10	1.40
		$7G_X$	20.0	27.0	17.0	7.3		3.30	3.95	2.50	2.15
10083		$1G_X$	8.0	26.0	7.0			1.50	2.45	1.10	1.35
		$10G_X$	26.0	28.0	22.5	10.8		3.30	4.10	2.80	2.10
0404353084	Donaghy	$1G_z$	6.5	26.0	10.0			1.30	2.00	.90	2.55
		$3G_z$	6.5	26.5	20.0		3.0	1.70	3.25	1.50	2.75
4085		$1G_z$	6.5	26.0	10.0			1.30	2.15	.95	2.60
		$4G_z$	6.5	26.5	25.0		4.0	1.80	3.40	1.50	3.00
0406353086	Harpel	$1G_z$	6.5	26.0	10.0			1.80	1.80	.80	2.70
		$3G_z$	6.5	26.5	20.0		3.0	2.30	3.50	.80	2.90
(3-1/2)087		$1G_z$	6.5	26.0	10.0			1.85	1.85	.80	2.70
		$3.5G_z$	6.5	26.5	22.0		3.4	2.40	3.70	.80	2.15

TABLE XVIII
ACCELERATION TEST RESULTS

Run Number	Subject	"G" Test Level	Instrumentation Axis Acceleration "Divisions" X	Y	Z	Seat Axis Acceleration G G_{X2}	G_{Z1}	Total Deflection, Inches 1	2	3	4
4088		$1G_z$	6.5	26.0	10.0			1.90	1.90	.80	2.75
		$4G_z$	6.5	26.5	25.0		4.0	2.25	3.65	.80	2.15
0405353089	King	$1G_z$	6.0	26.0	10.0			1.15	1.50	.75	2.70
		$3G_z$	6.5	26.5	19.5		2,9	1.15	1.80	.70	3.25
(3-1/2)090		$1G_z$	6.0	26.0	10.0			1.15	1.60	.75	2.80
		$3.5G_z$	6.5	26.5	22.0		3.4	1.15	1.95	.70	3.20
4091		$1G_z$	6.0	26.0	10.0			1.15	1.55	.75	2.75
		$4G_z$	6.5	26.5	25.0		4.0	1.30	2.40	.65	3.35
0411303092	Lewandowski	$1G_x$	8.0	26.0	7.0			1.30	2.00	1.50	2.35
		$3G_x$	12.0	26.5	10.0	3.2		2.20	3.25	2.15	2.50
5093		$1G_x$	8.5	26.0	7.0			1.45	2.25	1.60	2.20
		$5G_x$	16.0	27.0	13.5	5.1		2.80	3.90	2.50	2.55
7094		$1G_x$	8.5	26.0	7.0			1.70	2.65	1.55	2.25
		$7G_x$	20.0	27.5	17.0	7.3		3.50	4.20	2.75	2.65
10095		$1G_x$	8.5	26.0	7.0			1.70	2.60	1.65	2.20
		$10G_x$	26.0	29.0	22.5	10.5		3.65	4.40	3.30	2.60
0512303096	Chambers	$1G_x$	7.0	25.5	11.0			1.75	1.75	1.10	1.80
		$3G_x$	11.0	26.0	14.0	3.2		2.70	2.80	1.25	2.10
5097		$1G_x$	7.0	26.0	11.5			1.60	1.70	1.10	2.00
(stop-pulse)		$5G_x$	15.0	26.5	17.5	5.4		3.20	3.50	2.00	2.40
5098		$1G_x$	7.0	26.0	11.5			1.50	1.90	1.15	2.10
		$5G_x$	15.0	26.5	18.0	5.4		3.15	3.60	2.30	2.45
0509303099	Kinkade	$1G_x$	7.0	26.0	11.5			1.30	2.20	1.10	2.20
	1 min.	$3G_x$	11.0	26.0	14.5	3.2		2.40	3.45	1.70	2.50
0509305100		$1G_x$									
	30 sec.	$5G_x$									
0508303101	McClernan	$1G_x$	7.5	26.0	11.5			1.75	1.60	1.15	2.00
	1 min.	$3G_x$	11.5	26.5	15.0	3.2		3.15	3.20	2.00	2.30
5102		$1G_x$	7.5	26.0	12.0			2.20	2.05	1.20	2.00
	30 sec.	$5G_x$	15.0	26.5	18.0	5.1		3.65	3.70	2.60	2.50

TABLE XIX
ACCELERATION TEST RESULTS

Run Number	Subject	"G" Test Level	Instrumentation Axis Acceleration "Divisions"			Seat Axis Acceleration G		Total Deflection, Inches			
			X	Y	Z	G_{X_2}	G_{Z_1}	1	2	3	4
0507303103	Thayer	$1G_x$	7.5	26.0	11.5			1.20	1.65	1.30	2.10
	1 min.	$3G_x$	11.5	26.5	14.5	3.2		2.80	3.40	2.10	2.45
		$1G_x$	7.5	26.0	11.5			1.70	2.20	1.40	2.10
	30 sec.	$5G_x$	15.0	27.0	18.0	5.1		3.40	3.80	2.65	2.55

TABLE XX

SUMMARY OF ACCELERATION TEST RESULTS

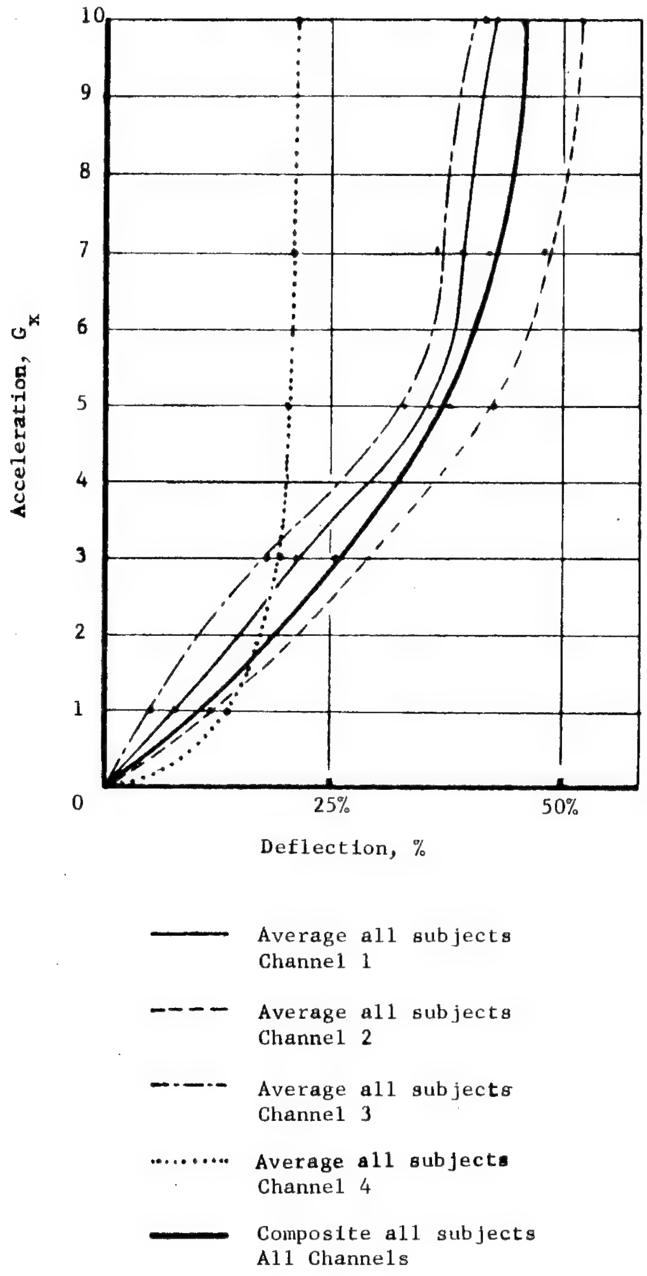
+ G_x Test Summary

	HUMAN SUBJECTS					DUMMY			
	1 S-1	2 L-1	3 T-1	3 HEL	4 IT	1 S-1	2 L-1	3 T-1	4 IT
1 G_x	.47	.68	.30	.28	.82	.20	.20	.10	1.20*
3 G_x	1.25	1.74	1.51	.79	1.07	.45	.35	.65	1.15
5 G_x	1.97	2.56	2.14	1.39	1.20	.10	1.00	1.30	1.20
7 G_x	2.38	2.86	2.17	1.84	1.25	.60	1.50	1.05	1.20
10 G_x	2.49	3.13	2.54	2.05	1.28	1.05	1.85	1.90	1.20
15 G_x						1.50	2.30	2.05	1.00
20 G_x						1.75	2.70	2.20	1.05
25 G_x						1.80	2.80	2.25	1.05
30 G_x						2.00	3.00	2.30	1.10

+ G_z Test Summary

	HUMAN SUBJECTS					DUMMY			
	1 S-1	2 L-1	3 T-1	3 HEL	4 IT	1 S-1	2 L-1	3 T-1	4 IT
1 G_z	.25	.43	.20	.30	1.59	0	.40	.40	1.05*
3 G_z	.41	1.11	.20	.30	2.03	0	.45	.40	1.40
4 G_z	.43	1.36	.23	.33	2.13	0	.45	.35	1.70
5 G_z	.33	1.09	.29	.60	2.50	.1	.45	.30	1.90
6 G_z	.13	1.20	.13		2.70	.1	.50	.20	2.10

* Cushion Deflection in Inches



CUSHION DEFLECTION AS A FUNCTION OF G_x

FIGURE 72

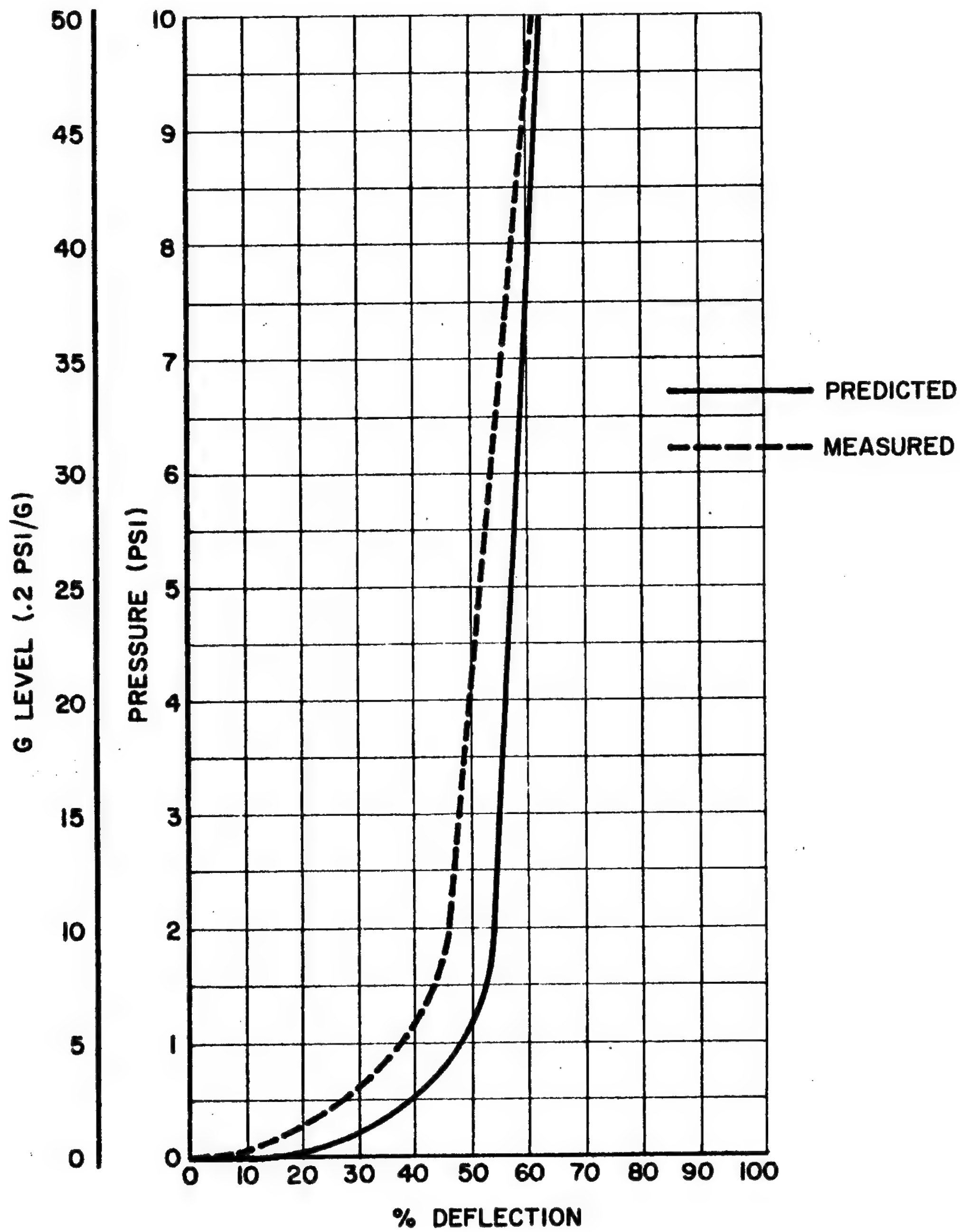

G LEVEL (.2 PSI/G)
0
5
10
15
20
25
30
35
40
45
50
PRESSURE (PSI)
0
1
2
3
4
5
6
7
8
9
10
0
10
20
30
40
50
60
70
80
90
100
% DEFLECTION
PREDICTED
MEASURED

FIGURE 73

UNIVERSAL COUCH PROGRAM TAPE #2

Subj: Mor

Proj. Officer: L. Hitchcock

Proj. Officer: First run will be 3G. Standby for dynamic manned run. Dynamic run-manned Run #0201303028. $3G_x$ following normal calibrated haversine.

Pilot: At 1 G in this position it is extremely comfortable. Back angle is pretty slack. Tendency is to feel head is down. Really felt good and you really sink in the couch. I could feel myself going back, I was holding onto the handgrips and I would say that I had at least ½ to 1" displacement to the rear on my handgrips.

Proj. Officer: Did you feel that you were sinking down approximately the same throughout or did you seem to sink in some spots more than others?

Pilot: Hard to say, I think I felt that it crossed my back first and then I realized that my arms and everything else were sinking back in the couch. The handgrip started to drag backward with me. It felt fairly evenly distributed, it really felt good. I don't know if it was couch or just the G but it really was nice.

Comment on displacement Lloyd. I should note that the only thing that did not appear to displace evenly was the back of my legs. I can tell a little more as we get more G.

Proj. Officer: During G_x series, pilot will remain in the recline position unless directed otherwise by the Medical Officer.

Repeating next run dynamic run 5G eyeballs in -0201305029 (Run starts)

Pilot: I feels so good. Feel wonderful, this couch is just magnificant - no problem breathing (during run) - just a little cough when I came off G. Ready to go again. At G it is a very, very nice sensation I just can't explain it. The handgrip is very, very functional and it worked beautifully as soon as the couch starts to yield, your handgrips start to come back with you, very smoothly the whole thing is a beautifully coordinated -------- (End Tape)

Pilot: I was trying to explain, the couch is extremely comfortable, I would say there was a considerably significant improvement over the hard couch, in that this couch yields very coordinated with the G. It is beautiful yielding sensation - the other couch did not have the yield the way this one does - it is extremely comfortable, the one thing I dislike are the supports behind my legs - they do not yield as the rest of the couch does - and I noticed this very much at G because the rest of the couch is formed around me and yield into it. It seems my legs are still just lying here on a board and it is disappointing because the rest of the couch is so nice. The other thing is the restraints do little or nothing for me. They are very loose right now because I slumped back into the couch. I don't particularly like them, I think they should be more comfortable and more positive on the knees. As far as the shoulder restraint goes, I would think that I would much prefer the standard shoulderstrap with the inertial wheel on it.

The seatbelt is very good, extremely good, comfortable.

Proj. Officer: Don, do you feel that if we gave you the single vector with no deviation, would you feel any need for restraint at all?

Pilot: No, I think it is a matter of psychology. I feel secure with the seatbelt at a minimum anyhow. I don't believe it is a function of the couch, it is just a matter of psychology. I wish I could explain this feeling, it is like nothing I have ever felt before, you really sink into this thing and it is so beautifully coordinated with the G. Let's go for 7 G.

Next run will be dynamic run 7G eyeballs in-run #0201307030

Pilot: One more comment. I felt a proportional change from 3 to 5 G as far as couch deflection is concerned. I was aware that I sunk deeper into the couch at 5 G.

I would like an event mark at the end of this run. I will explain later. (Run begins) Here we go-beautiful on the way up - really, really nice, feels good, very nice. (During run) Comment on that event - at that point coming down at peak, there is an abrupt stop in here, I don't know where I am on that. No trouble breathing - no pain anywhere, no complaints. Ready for another run, beautiful.

Comments on couch - I think on this run I had a tendency to feel like it was folding in the middle - in other words, I was straining on my ----- heel, the backs of my leg and I felt like my body started to go deeper than my head, however, I would rate it this way, I would rate that the back of my legs did not yield, my head yielded practically the best and my torso yielded best of all . I did have a tendency under that high G to feel like I was beginning to

Pilot: fold in the middle - lean forward. I think this could be improved in that the balance of seating does not appear to be as evenly distributed as the 3 and 5 G runs. Again I would rate my biggest problem would be the one with the legs.

Proj. Officer: How did the support around the sides feel - did it seem to wrap around you?

Pilot: Yes, this is the whole point of this - can't explain this couch it seems as it approaches the G it seems to go below come up around and hug you. It just gives you, I don't know who to explain it, it is a feeling of confidence like I could take any kind of G. It is really great, I have never ridden anything like this. I did not like this folding in the middle.

Proj. Officer: Did you feel like you head bobbed?

Pilot: Negative. It felt like it would not go down anymore, it wasn't bobbing. My torso was going deeper than the rest of my but it -------

Proj. Officer: Did you feel like the bottom part of your leg and your thigh were increasing in angular? They just don't sink at all?

Pilot: Yes, they just don't go at all.

Next run will be a 10G eyeballs in run.

Pilot: Before we go, I think we better have something under this cup at 10 G. This cup has a tendency to whip off my chin. I would like to comment again on these handgrips, they are marvelous as opposed to other systems that I have been in. They, as you get under G you know you are straining and you are reaching and trying to grab your controller, here your grip never really gets tight on your controller, you just sort of sit here and relax and it comes back with you.

Med. Officer: Do you feel this might be an advantage for what we normally consider the nondeforming solid couch situation?

Pilot: I don't know, I would say even under a solid couch that you have the tendency of straining to reach forward and it is not apparent here at all. Incidentally, as far as temperature goes, I do feel warm, from the shoulder blades down to about the ----------, it is warm but not uncomfortably so.

We will commence run dynamic, conditions 10 G G_x run #0201310031.

Pilot: I will give you an event mark when I am feeling I am folding in the middle. Starting to sink. I am fine. Just a little cough that is all. No pain at all, vision is fine. I was looking at peak and saw no problem at all.

TAPE #4

Pilot: No more started to sink than I could feel myself hitting stop.

Proj. Officer: If we go to 12 would you give us a similar mark if you receive the same sensation.

Pilot: Yes, this is a false ------- where I start to yield.

Proj. Officer: I think Don, that what you will find that this is an actual stop but it is not a total deformation of the foam, it is merely where the force balances with the deformation and you stop moving. It, the mark occurred exactly as the G stabilized at peak.

Pilot: I would like to see this again at a little higher G if it if OK with Dr. ------

Comments are essentially the same as before. Everything was beautiful, back of legs are still a problem. I noted that the bottom effect this time which we look at again. I think at this G level, I couln't see any difference between the 3, 5, and 7th - you really feel like you are starting to work at peak, up until this time, it feels like the couch has done all the work for you, this is the first time it really feels like I was starting to do some work.

Proj. Officer: Don, when you felt you had bottom was it uniform all over except for the back of the legs, of course? You said you felt like you were going back pretty uniformly, did you feel like you bottomed pretty uniformly?

Pilot: Negative, I think I felt like rolling along the torso. Only along the torso. Incidentally, Mac, the top part of my knee restraint is not even touching the couch.

Proj. Officer: One would expect that it wouldn't in that particular case. If you are sitting up it is going to hold you into the couch. Right now you really don't need any restraint. None of them are doing anything for you right now except that security blanket.

Don I have a feeling that it is lack of motion you are feeling, seeing as you felt this just about at peak 7, I guess it was and at peak 10.

Pilot: This is what I want to see - I will give you a mark if I see it at 12.

The next run will be a dynamic run, 12 G run eyeballs in. Run #0201312032.

Proj. Officer: Don you will again give us a hack when you feel that the formation is completed. CC Stop pushed by Paul communications clear to Med. Off.

Med. Officer: Medical emergency.

Pilot: Greyout, I greyed out.

Proj. Officer: Leave him on his back.

Med. Officer: How are you now Don?

Pilot: I am fine. The first effect was on the bottom and then I signaled a hack when I started to grey, then when I went partially out, I hit the stop the Run. I am terrible, you have to get me out of here.

TAPE #11 - $3G_z$ Run

Pilot: Mor

Proj. Officer: Hitchcock

Pilot: I feel excellent. No greyout.

Couch was very good, it provided a lot more support than I had anticipated it would sitting in it a 1 G it's extremely comfortable at $3G_Z$.

Run #0301354064

Subj: Mor

$3.5G_z$ I started to grey out that time, I did not lose my central vision however. The greyout came on very gradually. The couch provided a lot more support than I had anticipated, it did feel like I had reached a point in the seat pan where I stopped motion. One problem that I had particularly in this task is some place to put my feet, right now I have my feet riding on the side rails of the feet cups and other than that no problem.

$4.5G_z$ Went completely black. Evidently I hadn't been straining as hard that time as I had been before because I'm much more relaxed at the end of this run than I was last run. I have no idea how long I was blacked out. My comments about the couch are the same as before. The couch did provide a great deal more support than I had anticipated. I think probably with a better foot arrangement for me I could perform better straining patterns.

AIRCRAFT ARMAMENTS, Inc.

UNIVERSAL COUCH PROGRAM

PRE-SESSION QUESTIONS

Answer the following questions to the best of your ability. If the meaning of any question is not clear, do not hesitate to ask for explanation.

Name: Donald A. Morway Date: 11 January 1965

Height: 5'7" Weight: 150 Time: 1400

A. Personal History

1. Are you currently experiencing any discomfort due to any of the following conditions?

____	a)	Allergies	____	g)	Dental trouble
____	b)	Headaches	____	h)	Intestinal trouble
____	c)	Earaches	____	i)	Respiratory trouble
____	d)	Visual fatigue	____	j)	Dizziness
Minor x	e)	Sinus trouble	____	k)	Skin irritations
____	f)	Colds	____	l)	Other

COMMENTS:

2. Do you currently feel any stiffness or soreness in the muscles of any of the following regions of the body?

____	a)	Neck	____	f)	Legs
____	b)	Arms	____	g)	Other
____	c)	Back			
____	d)	Chest			
____	e)	Abdomen			

COMMENTS:

OTO/ML/50/12-64

3. Have you ever had "G" experience with a "G" couch? (Not a seat)

_x_ Yes

___ No

What kind of couch? Gemini Mercury, Apollo

How long ago? 3 months

How many G? 10

What type of G field?

_x_ EBI

___ EBO

___ EBD

Donald Morway

AIRCRAFT ARMAMENTS, Inc.

UNIVERSAL COUCH QUESTIONNAIRE

I. Indicate the number of hours sleep you had last night. 6

II. COUCH EVALUATION

A. In the questions listed on this page, try to evaluate the couch in terms of the comfort that it provided.

1. What is your impression of the degree of comfort that the couch provided?

x a) It is the most comfortable couch I have ever sat in.
___ b) It is extremely comfortable.
___ c) It is moderately comfortable.
___ d) It is mildly comfortable.
___ e) It is neither comfortable nor uncomfortable.
___ f) It is mildly uncomfortable.
___ g) It is moderately uncomfortable
___ h) It is extremely uncomfortable.
___ i) It is so uncomfortable that I cannot tolerate it.

2. Did the couch display any adverse effects during acceleration?

Back of legs did not yield; at ten and above head and shoulders did not yield as much as torso; therefore, increased head angle, I think this was significant factor in grey out.

B. Evaluate the couch on the basis of how you felt.

1. Describe the degree of discomfort that you felt in the following body regions.

	None	Slight	Moderate	Severe	Very Severe	Intolerable
a) Neck						
b) Shoulders						
c) Back						
d) Buttocks						
e) Thighs						
f) Legs			x			

2. Describe the sensations you felt in the following body regions. If none of the sensations listed apply to a particular region, leave a blank.

All G levels increased with G.

	Excessive Pressure	Stiffness	Ache	Soreness	Prickling Sensation	Numbness
a) Neck						
b) Shoulders						
c) Chest						
d) Abdomen						
e) Thighs						
f) Knees (back of)	x					
g) Feet						

4.25

OTO/ML/100/12-64

C. Evaluate the following characteristics of the couch. Put a check mark next to the statement that applies.

The comfort liner was	___	too firm
except back of legs	x	just right
	___	too soft
The comfort liner was	___	too thick
	x	just right
	___	too thin
The "pocket" of the couch was	___	too wide
	x	just right
	___	too thin
The "pocket" of the couch was	___	too long
	x	just right
	___	too narrow
My head position was	x	too high
	___	just right
	___	too low
The left arm position with respect to the grip was	___	too close
	x	just right
	___	too remote
The right arm position with respect to the grip was	___	too close
	x	just right
	___	too remote
The angle between thighs and torso as it affects comfort was	___	too small
	x	just right
	___	too large
The angle between thighs and shanks as it affects comfort was	___	too small
	___	just right
	x	too large - under G
The angle between shanks and feet as it affects comfort was	___	too small
	x	just right- no restraint
	x	too large - restraint

III. HARNESS EVALUATION

Evaluate the following characteristics of the harness. Put a check mark next to the statement which applies.

A. Lap strap

The lap strap was
- ____ too wide
- _x_ satisfactory
- ____ too narrow

The lap strap was located
- ____ too high
- _x_ satisfactory
- ____ too low

B. Shoulder straps

The shoulder straps were
- _x_ too wide
- ____ satisfactory
- ____ too narrow

The shoulder straps put excessive pressure on
- ____ top shoulders
- ____ chest
- ____ no particular area
- _X_ under arms

IV. EVALUATION OF DEGREE OF FATIGUE FELT

Describe the degree of fatigue that you feel at this time:

____ a) I am the most fatigued that I have ever been.
____ b) I am extremely fatigued.
____ c) I am moderately fatigued.
____ d) I am mildly fatigued.
____ e) I am neither fatigued nor rested.
_x_ f) I am mildly rested.
____ g) I am moderately rested.
____ h) I am extremely rested.
____ i) I am more rested than I have ever been.

UNIVERSAL COUCH PROGRAM

V. POST-RUN PILOT CONDITION QUESTIONNAIRE

1. Did you have any pain? Describe completely.

   No.

2. What was your vision like? Describe. (acuity, brightness, color, field)

   Greyout at 12 G_x

3. Did you feel weak or dizzy. Describe. (When, how long, how much)

   Yes, coming out of greyout.

4. Were you sweating? (When, where, how long, how much)

   Back very slightly.

5. Were you nauseated? (When, how long, how severe)

   No.

6. Did you have "indigestion"?

   No.

7. Did you have need to void? (When, how severe)

   Yes, slight.

VI. This part of the questionnaire gives you an opportunity to make any comments that you wish to make about the couch, your comfort state, and to offer any suggestions that you like. Write freely, and in as much detail as possible. You may continue your comments on the back of this page.

1. An exceptional experience almost enjoyable at higher G's and in fact very enjoyable at 3 - 5 - 7 G's.

2. Very comfortable except for feet and legs as described on tape.

3. Increase of head angle at 12 G's appeared to be primary reason for greyout - should be corrected.

4. Better than expected support at other G vectors at 1 G except EBO but this is restraint and not couch.